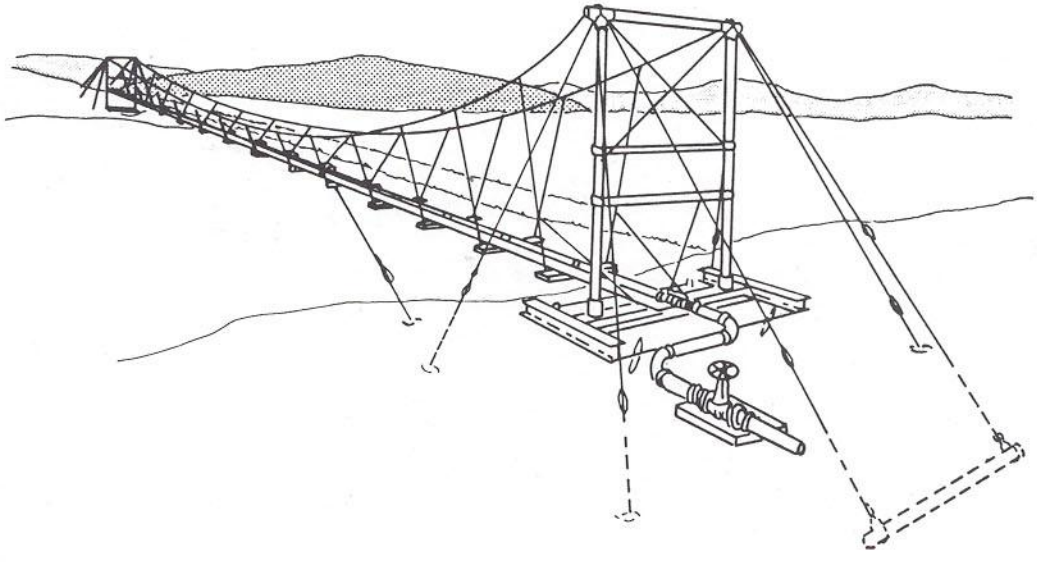
FM 5-482

Military Petroleum Pipeline Systems



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MILITARY PETROLEUM PIPELINE SYSTEMS

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PREFACE

Purpose

This manual provides the fundamentals of planning and construction of military petroleum pipelines. The manual also provides detailed information for construction personnel on the installation and repair of military pipeline systems. It delineates unit responsibilities, whenever possible, due to the large number of units with specialized skills required to establish a bulk-fuel distribution system.

Scope and Applicability

This manual can be used by any planner at company level and above. However, it was developed primarily for engineer commanders and staffs to design petroleum pipeline distribution systems. Use of this manual is also applicable to quartermaster commanders and staff for the operation of these bulk Class III systems.

The proponent for this publication is HQ, TRADOC. Submit changes for improving this publication on Department of the Army (DA) Form 2028 (Recommended Changes to Publications and Blank Forms) and forward it to Commandant, US Army Engineer School, ATTN: ATSE-T-PD-PM, Fort Leonard Wood, MO 65473-6650.

The provisions of this publication are the subject of international agreement STANAG 2115 LOG (Edition 4), *Fuel Consumption Unit.*

Unless otherwise stated, masculine nouns and pronouns do not refer exclusively to men.

DANGER

Suspend all handling of the pipeline system when an electrical storm is within a 5-mile radius of your operation, during high winds, or when your commander notifies you.

Chapter One. Bulk-Fuel Distribution System

This chapter implements STANAG 2115 LOG (Edition 4).

1-1. Introduction.

a. *The Distribution System.* The military's ability to move and fight depends on its fuel supply. In modern warfare, bulk petroleum makes up over 70 percent of the tonnage moved in the theater of operations (TO). The availability of fuel depends on the location of the TO. In industrialized areas, initial supplies could be obtained locally. Tankers will bring in subsequent supplies. Major portions of the distribution system, such as storage tanks, may already be in place. The existing system may have to be renovated or supplemented with coupled pipelines, hose lines, and temporary storage tanks. In undeveloped areas, tankers bring in initial fuel supplies. The Army supplies its own distribution system. The quartermaster petroleum group is responsible for the supply and distribution of bulk fuel in a TO.

A bulk-petroleum distribution system is the network that gets bulk fuel to using units. The system can consist of ocean-tanker loading and unloading facilities, storage terminals, pump stations, pipelines, hose lines, Class III supply points, tank vehicles, and rail tank cars. In an undeveloped TO, the bulk-petroleum distributions system (Figure 1-1, page 1-2) consists of tactical petroleum terminals (TPTs), hose lines, fuel-system supply points (FSSPs), and tank vehicles. In a developed TO, the same items mentioned above normally consist of fixed facilities (Figure 1-2, page 1-3). Pipelines are used as far forward as the corps' rear area. The rest of the system in the corps and division areas consists of portable facilities.

The basic petroleum-operating concept is to keep storage tanks full at all times. The schedule for fuel movement through the system is based on storage capacity and product demand. Constant communication between the distribution and storage facilities is essential during construction and operation of the system. For more information, see FMs 10-18 and 10-67.

(1) In an Undeveloped TO. Bulk fuels are received in the undeveloped TO in over-the-beach operations using TPTs. Hose lines or coupled pipelines initially carry the products inland, and the Army transports the fuels to the ground forces, where possible. Coastal tankers may be used to move products from deep draft tankers to moorings in waters too shallow for larger ships. Bulk fuel is transferred by flexible hose lines to tank farms, which are made up of steel or collapsible, fabric storage tanks. The petroleum supply system in an undeveloped TO includes tanker mooring facilities, floating hose lines, submarine pipelines, and inland tank farms and terminals that use hose lines and collapsible tanks. The system also includes pump stations, flexible hose lines, coupled pipelines, and tank vehicles. Bulk fuel is moved from base terminals and rear storage locations to the combat zone, using flexible hose lines.

Coupled pipelines are used when the beachhead is expanded. Initially, tactical air bases are connected to the main hose line or pipeline and to the appropriate tank farm by hose line. The

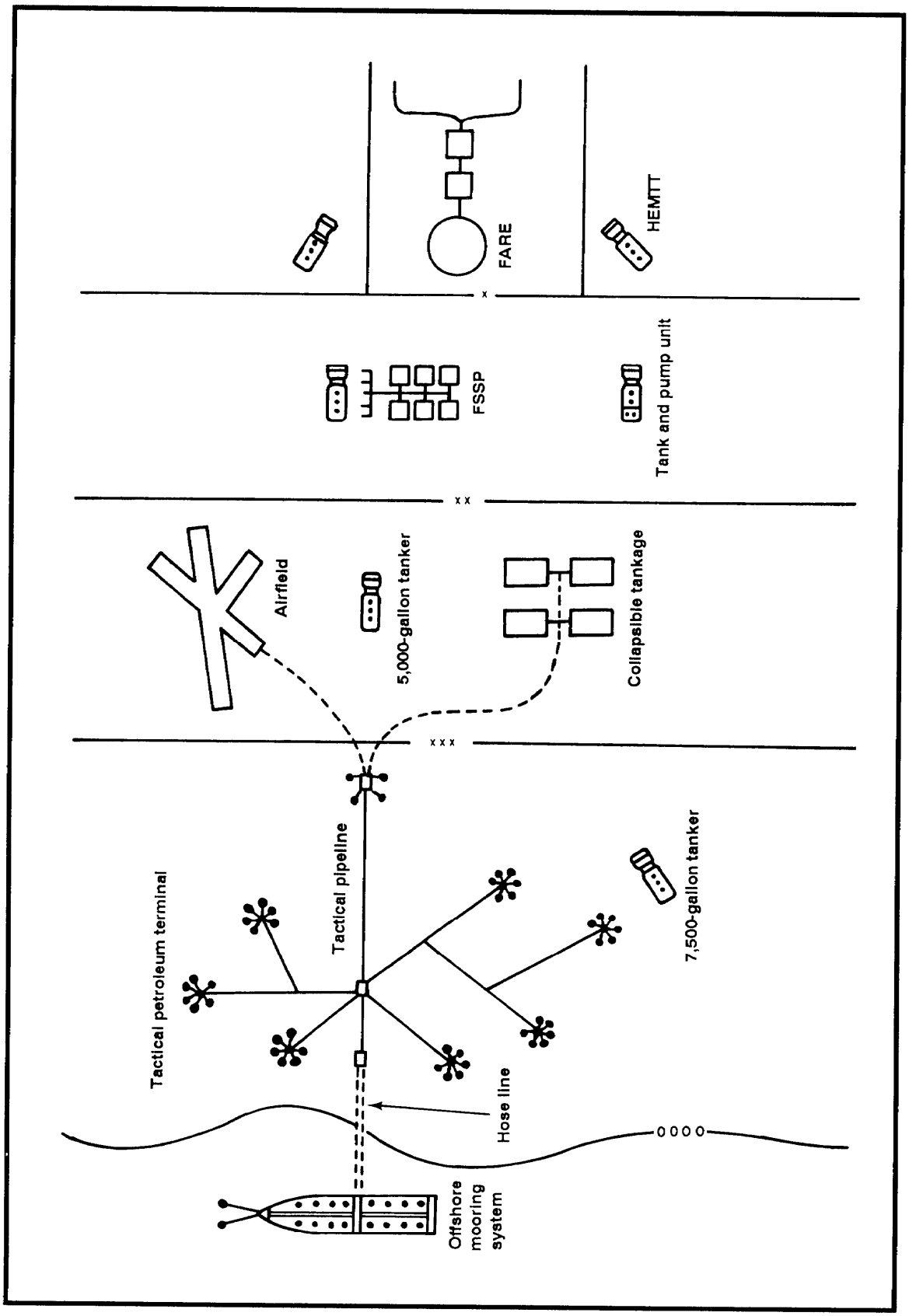


Figure 1-1. Bulk-petroleum distribution system in an undeveloped TO

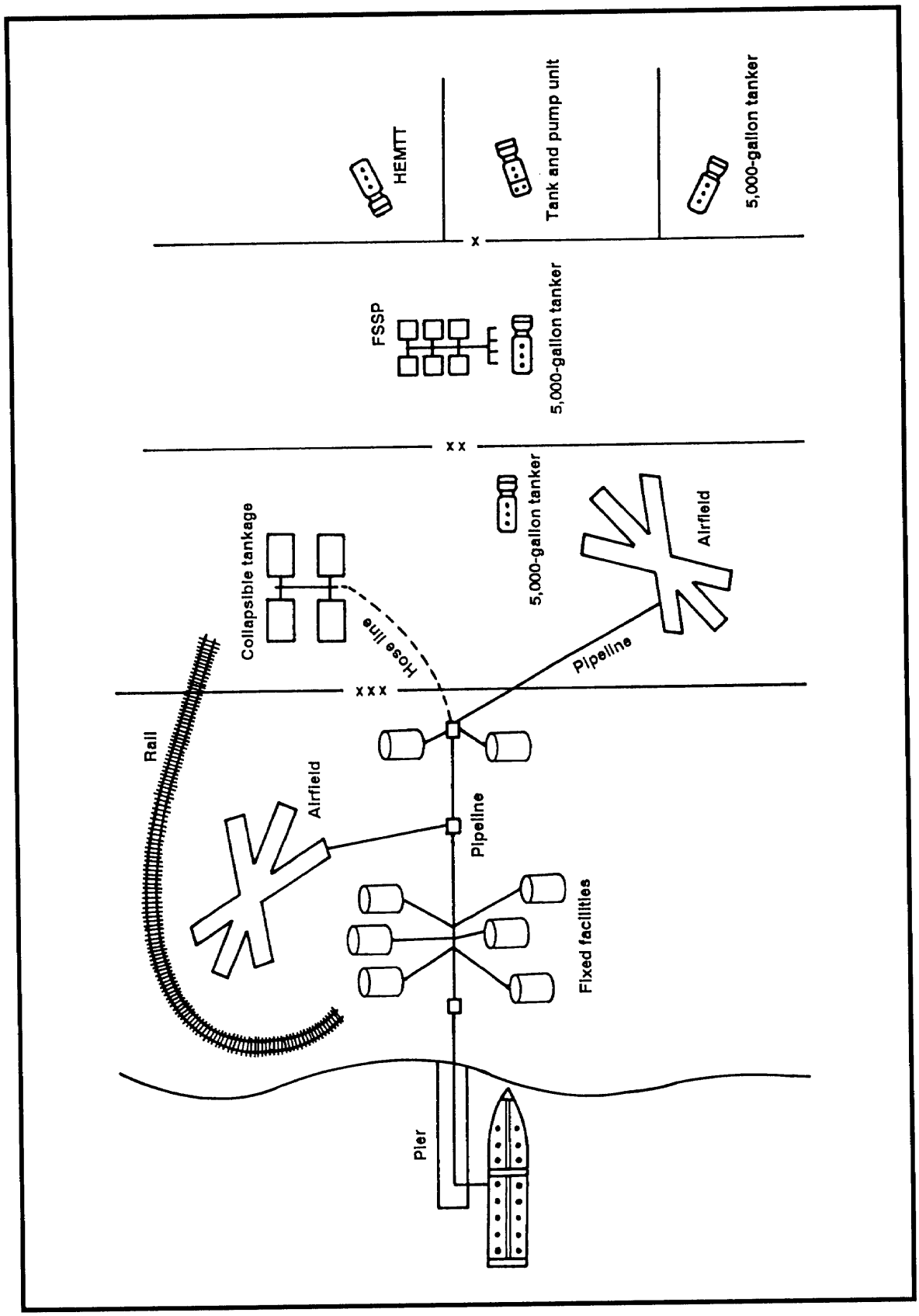


Figure 1-2. Bulk-petroleum distribution system in a developed TO

pipeline and hose-line systems extend as far forward as possible, usually into the corps' rear area. The hose-line system is a rapidly deployable system. The initial system will probably consist of the TPT, portable pumps with capacities of 600 and 800 gallons per minute (GPM), hose lines, and collapsible storage tanks. As the beachhead and the theater are expanded, rigid tactical pipelines and fixed pumping assemblies will be required. Other means of delivery, such as tank vehicle, barge, and aircraft, will be incorporated into the system, as required.

(2) In a Developed TO. Bulk fuels not locally procured are received from ocean tankers at TPTs. Bulk fuels are transferred by pipeline to tank farms. The system includes discharge facilities, which include tanker moorings, piers, docks, and piping manifolds at ports, sea terminals, or at other points of entry; inland tank farms; storage terminals; and other petroleum-storage facilities. The system also includes pump stations and pipelines.

Large-scale combat operations may justify construction of welded or coupled pipelines to move bulk fuels from the communications zone (COMMZ) storage locations to the combat zone. When possible, the pipeline system services air bases and tactical airfields. Hose lines are used to service small-volume or temporary large-volume requirements. The pipeline system extends as far forward as possible, usually into the corps' storage sites.

Since bulk petroleum makes up over 70 percent of the tonnage moved in the TO, pipelines significantly reduce other transportation requirements (rail and highway) and congestion. The system is supplemented by other means of bulk delivery: barges, rail tank cars, tank vehicles, and aircraft. Branch lines are used when it is practical to supply users from the main pipeline. Tank vehicles, rail tank cars, and hose lines are used to move bulk-petroleum products from general-to-direct-support echelons. Bulk transporters may move bulk fuel from the direct-support echelon to using units. Using units are authorized organizational equipment to receive the bulk products and to refuel their vehicles and aircraft without resorting to cans and drums.

b. *Planning.* Planning for petroleum supply support generally parallels the planning process in FM 101-5. Time, space, distances, terrain, existing resources, requirements, and operating environment are planning factors. One of the most important planning elements for petroleum support is requirements computation. Supply publications, such as Supply Bulletin (SB) 710-2, FM 101-10-1/2, and Standardization Agreement(STANAG)2115, contain planning data for Class III supplies. The petroleum planner should use them in coordination with engineer theater development planning.

(1) Elements. Petroleum supply planning involves the following major elements:

- Amount and type of product to be distributed (requirements).
- Receipt and distribution points (storage locations).
- Distribution system or method (transportation mode).
- Equipment to be used (pump, pipeline equipment, rail, truck, boat).
- Organizations and personnel required to operate the system and its equipment (units).

(2) Considerations. The petroleum supply system must be designed for the type of operations and climate of the specific theater. Plans must take into account the following:

- Mission and forces (size and composition) to be supported.
- Requirements of the supported force.
- Climate requirements.
- Availability of transportation units (including the host nation) to move the petroleum distribution equipment from its theater entry port inland to the construction staging areas to provide required support.
- Speed with which pipelines and hose lines can be constructed and extended.
- Requirements for terminals, offshore unloading facilities, and distribution points.
- Requirements for both bulk and packaged products.
- Availability of petroleum operating units and other units needed to construct, install, and maintain petroleum distribution and storage facilities and communications equipment.
- Terrain features, which impacts on installing petroleum facilities and fuel-usage factors.

(3) Categories.

(a) Logistical. Logistical planning requires translating factors such as troop strengths, numbers and types of fuel-consuming equipment and vehicles, and tactical objectives into specific fuel requirements and distribution plans. Planning starts before the actual operations at the TO and theater-army levels. The purpose of the planning is to ensure that products, distribution facilities, and operating units and personnel will be available when needed.

(b) Operational. Operational planning includes planning both for reaching the rated capacity of the distribution system and for maintaining that capacity to meet requirements placed on it. This planning is carried on along with operations. Revisions may be necessary because of tactical developments, losses in handling capacity due to enemy action, and other factors that keep the system from operating as planned.

c. *Supply Levels.* DA prescribes supply levels for the theater army in terms of days of supply. The theater army commander prescribes levels for the combat zone and the COMMZ. For planning purposes, a 30-day (minimum) theater supply level should be established for bulk fuel in the developed theater. In reality, the level may be greater than 30 days, depending on available tankage and other factors (Figure 1-3, page 1-6). The major portion of the theater level is maintained in the COMMZ. When planning, supply levels must take into account the needs of all users, including Air Force, Navy, and allies (when so designated).

d. *Host-Nation Support.* In wartime, US logistical support may not be readily available. US combat forces may be supplied with common items and services, through agreements, from the host nation. The type and amount of support should be specified in the agreements and included in the wartime logistical plans from all nations concerned. The amount of support, civil or military, that a host nation can provide depends on its national laws, industrial capability, economy, and willingness to give such support. Even if it is difficult to obtain host-nation support agreements, they should be pursued. Host-nation resources will most likely support the COMMZ, the corps, and the divisional areas, as appropriate. Host-nation support, if available, can significantly reduce support requirements.

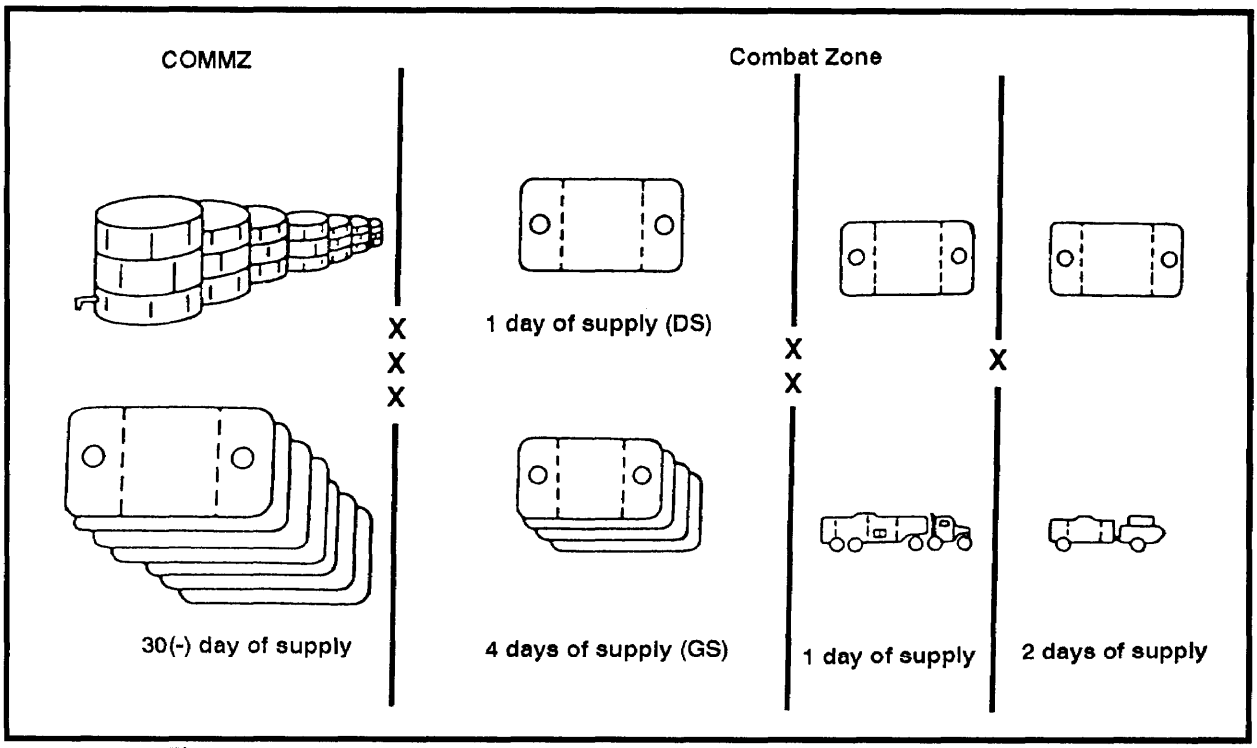


Figure 1-3. Bulk-fuel supply breakdown (minimum days) for storage

Procedures for mutual support among North Atlantic Treaty Organization (NATO) nations are contained in directives agreed on for civil military cooperation (CIMIC). A host nation can be requested to provide civil resources, including facilities, food, services, or labor. National or allied commanders submit requests for CIMIC support to the territorial command of the host nation. Where possible, and preferable, national/allied CIMIC agreements are made with the host nation in peacetime.

e. *Pipelines.* Pipelines are the most economical and rapid means of transporting large quantities of fuel between two points. Based on the planning considerations, a fuel-supply planner will consider using either a hose-line, coupled, or welded pipeline system.

(1) Hose Lines. Military hose lines are available in sizes from 2 to 6 inches with strengths up to 740 pounds per square inch (psi). Hose lines are used in TPTs, in ship-to-shore tanker unloading (or loading) lines, and for overland delivery of petroleum products within a 5-mile radius, based on mission analysis. Most hose lines can be installed quickly with minimal manpower and equipment. However, hose lines are much more susceptible to damage and cannot transport as much fuel as metal pipelines. New technologies appear to be reducing the hose-line disadvantages. Durability has been enhanced and working pressures increased so that hose lines may provide a viable pipeline alternative in the future. High-pressure hose lines are currently being tested for their shelf-life potential.

(2) Coupled Pipelines. Military coupled pipelines are available in aluminum and steel. The steel pipe is grooved at the ends and uses a split-ring coupling and gasket for sealing. The aluminum pipe also is grooved at both ends and uses a hinged snap-joint coupling. Coupled pipelines are

always surface-laid. Coupled pipelines can be used in an undeveloped TO and can be economical for distances over 5 miles. Coupled pipelines can be installed much quicker and with less skilled labor than buried welded pipelines. However, coupled pipelines are vulnerable to sabotage and normal damage and wear. The aluminum pipe, as a component of the Inland Petroleum Distribution System (IPDS), is the military standard for a coupled pipeline system. Aluminum pipes for the IPDS are 6 inches in diameter and are 19 feet long. The IPDS pipe is coupled with a hinged snap-joint coupling with either a one-piece or integral two-piece split-seal gasket. The hinged coupling provides improved coupling rates (less than 50 seconds per joint) over the bolted-style coupling used during Vietnam, which required an average of 5 minutes per joint.

1-2. Responsibilities.

a. *Theater Army.* Theater army headquarters provides broad planning guidance for Army petroleum support. The Theater Army Material Management Center (TAMMC) is the theater petroleum item manager for bulk-petroleum products. The TAMMC records consumption data and coordinates with the petroleum group to program future requirements. The theater army orders the required pipeline construction materials and coordinates the movement of the materials to the construction staging areas along the proposed pipeline route. The theater army coordinates with all host-nation petroleum suppliers.

b. *Quartermaster Branch.*

(1) Petroleum Group. This group has the mission from the theater army to plan, control, and supervise the operation of the fuel-distribution system. The group's headquarters develops requirements for petroleum-handling equipment, facilities, construction, and petroleum units needed to develop, operate, and maintain the system. It supervises two or more petroleum-pipeline and terminal-operating battalions, transportation motor transport battalions (petroleum, oils, and lubricants (POL)), and other units, as required.

(2) Petroleum Pipeline and Terminal Operating Battalion. This battalion--

- Supervises the operation and maintenance of a military petroleum distribution system or part of a system determined by geographic needs.
- Schedules and directs the flow of bulk-petroleum products through the pipeline.
- Coordinates the movement of bulk-petroleum products, using systems such as barge, rail, truck, or air.
- Supervises the quality surveillance of the petroleum products in their area of responsibility.
- Provides command and control for up to five petroleum-pipeline and terminal-operating companies, medium-truck companies, and other units, as required.

Petroleum Pipeline and Terminal Operating Company. This company's mission is to operate and maintain, on a 24-hour basis, a section of pipeline not to exceed six pipeline pump stations and one TPT. The company's maintenance capabilities include repairing and replacing valves, blinds, pressure gauges, meters, pump units, welded pipelines, coupled pipelines, hose lines, and related pipeline equipment.

c. Engineer Branch. Engineer support in the development of the bulk-fuel distribution system requires general and specialized construction skills. General engineer construction units are augmented with specialized units to accomplish the mission.

(1) Combat Heavy Engineer Battalion. This battalion is the primary military engineer unit to support the construction of the bulk-petroleum distribution system. (A corps combat engineer battalion could accomplish the mission, but at a slower rate.) The unit provides horizontal and general construction support for the pipeline construction mission. The engineer battalion is the higher headquarter of the specialized unit assigned to it for pipeline construction. Horizontal tasks include route clearing and leveling, pumping-station pad preparation, culvert construction, gap-crossing construction, TPT berm construction, and construction-staging-area preparation. General construction tasks include surveying and constructing the pipeline system.

(2) Engineer Pipeline-Construction Support Company. This unit provides the engineer battalion the technical expertise and specialized equipment for constructing the pipeline system. The unit has limited, independent capabilities to construct pipeline systems. The pipeline construction company can provide technical advisors to a battalion-size task force on a 24-hour basis. Specialized equipment includes bolster trailers, forklifts, 7 1/2- and 40-ton cranes, and small emplacement excavators (SEEs) with drivehead attachments (Figure 1-4). This unit does not have the movement assets to transport the pipeline construction materials from the storage areas to the construction staging areas.

d. *US Navy.* The US Navy is responsible for the installation of the Offshore Petroleum Distribution System (OPDS) and ship-to-shore pipeline to the high-watermark and the connections and operation of the beach-termination unit. They are also responsible for the installation and operation of the Single-Anchor Leg-Mooring System (SALMS).

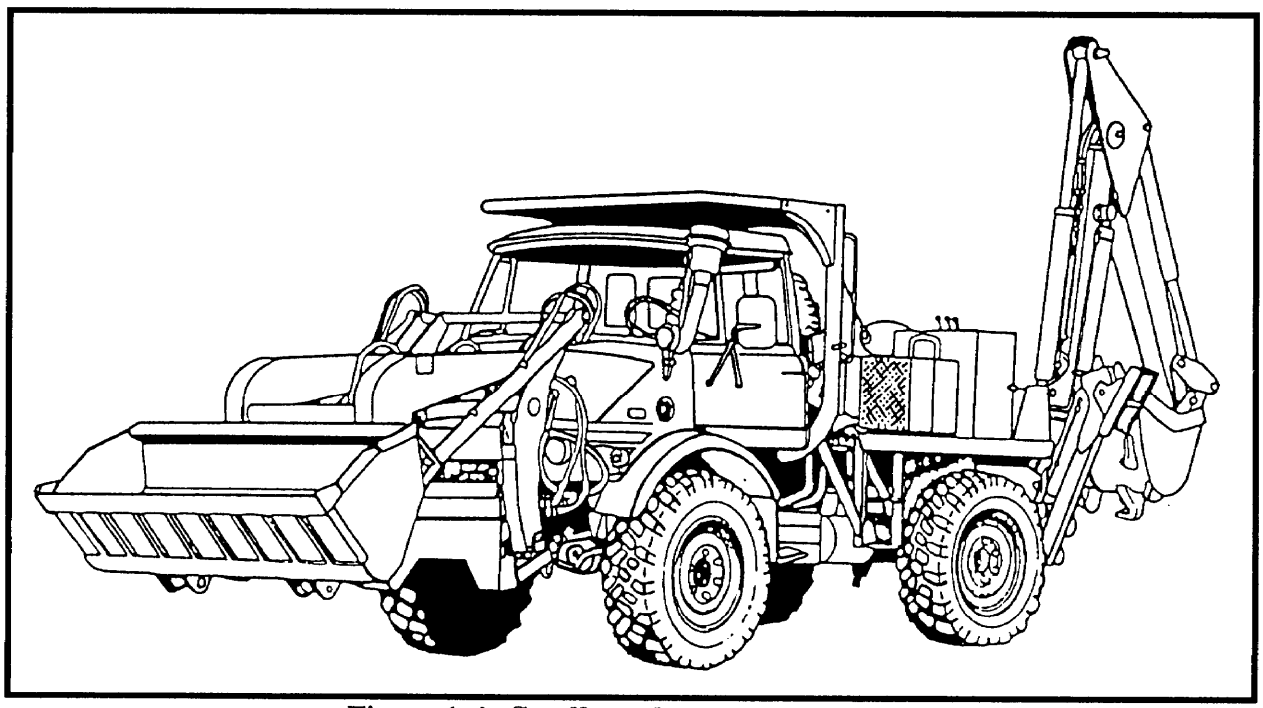


Figure 1-4. Small emplacement excavator

Chapter Two. Equipment

2-1. The Army Facilities Components System (AFCS). The AFCS consists of Technical Manuals (TMs) 5-301,5-302,5-303, and 5-304 that makeup a system for rapidly determining the Class IV materials, layout, and construction effort required. (TM 5-304 explains the terminology used in AFCS, such as *installations* that are made up of *facilities* which are made up of *items.)*

2-2. Aluminum Pipeline Facilities. Figure 2-1 shows the packaging symbols for the IPDS.

a. *5-Mile Pipeline Set.* This set consists of the pipes, couplings, and gaskets needed to build 5 miles of pipeline. The set also includes gate valves, check valves, vent assemblies, elbows, pipeline anchors, culvert materials, overcouplings, and repair clamps needed for a 5-mile section of pipe.

b. *Mainline Pumping-Station Set.* This set consists of pumps, gate valves, check-valve launchers, receivers, strainers, light sets, and pump shelters needed to construct a standard, mainline pumping station. Most mainline pumping-station kits include two pumping units to facilitate a 24-hour operation. Each pumping-station set differs slightly in its capabilities and component listings.

c. *Pipeline Suspension-Bridge Set.* Pipeline suspension-bridge assemblies are available in 100-, 200-, and 400-foot kits. A set consists of towers; guy wires; deadman anchors; main cables, suspenders, and cross bearers; staging board; tension cables; wind guys; and hand rope needed to construct the bridge. No special tools are required.

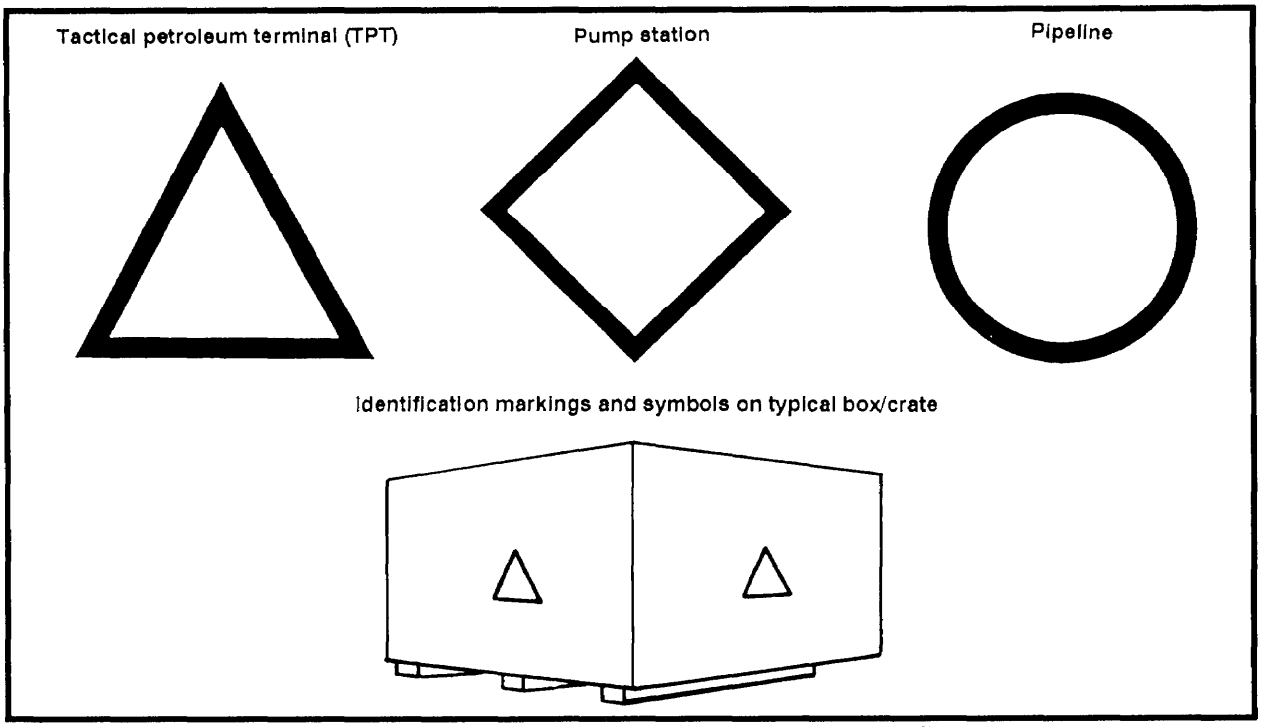


Figure 2-1. Packaging symbols for the IPDS

2-3. Pipeline Items.

a. *Pipes.* The different types of pipe used to construct military pipelines are coupled aluminum IPDS pipe, coupled lightweight steel pipe, and welded or coupled standard-weight pipe. The aluminum IPDS pipe--

- Has replaced the lightweight steel tubing.
- Comes in 19-foot sections with a 6-inch nominal inside diameter (ID).
- Is modified single-grooved at each end.
- Is connected with a snap-joint coupling.
- Is designed to be surface-laid, not buried, because of coupling and strength limitations.

See Table 2-1 for weight, dimensions, and strength of IPDS pipe and Figure 2-2 for a sample of the IPDS pipe.

Table 2-1. Pipe specifications

Nominal Size (in)	Outside Diameter (in)	Inside Diameter (in)	Wall Thickness (in)	Weight per foot (lb)	Standard Length (ft)	Maximum Safe Working Pressure (psi)
Aluminum IPDS Pipe (coupled)						
6	6.625	6.249	0.188	5.63	19	740
Lightweight Steel Pipe (coupled)						
4	4.500	4.350	0.7470	4.1	20	600
6	6.625	6.415	0.1046	8.5	20	600
8	8.625	8.415	0.1046	10.6	20	500
12	12.750	12.481	0.1345	20.0	20	400
Standard-Weight (API STD5L) Pipe (welded*/coupled)**						
4	4.500	4.062	0.219	10.00	20	1,700*/1,000**
6	6.625	6.187	0.219	15.00	20	1,200*/1,000**
6	6.625	6.065	0.280	19.00	20	1,500*/1,000**
8	8.625	7.981	0.322	28.55	20	1,300*/800**
8	8.625	7.875	0.375	33.05	20	1,400*
12	12.750	12.126	0.312	41.50	20	900*/800**
16	16.000	15.376	0.312	52.35	20	700*
20	20.000	19.250	0.375	78.70	20	125*
20	20.000	19.376	0.312	65.80	20	125*

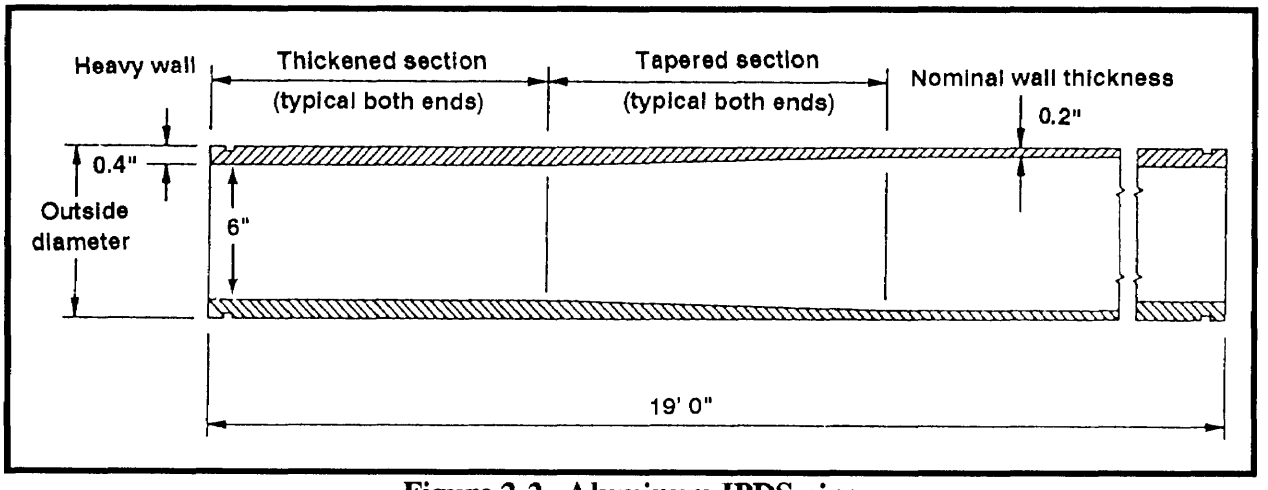


Figure 2-2. Aluminum IPDS pipe

b. *Aluminum Pipe Coupling.* The hinged snap-joint coupling, which is standard for single-grooved aluminum pipe, is available with either a one-piece separate gasket or a two-piece integral gasket (Figure 2-3). The coupling consists of two sections that are hinged together and a pin for closing the coupling over the pipe ends. The coupling and gasket are designed to seal under pressure and vacuum. The hinged coupling allows for a 2 percent deflection between joints and a maximum allowable working pressure (MAWP) of 740 psi.

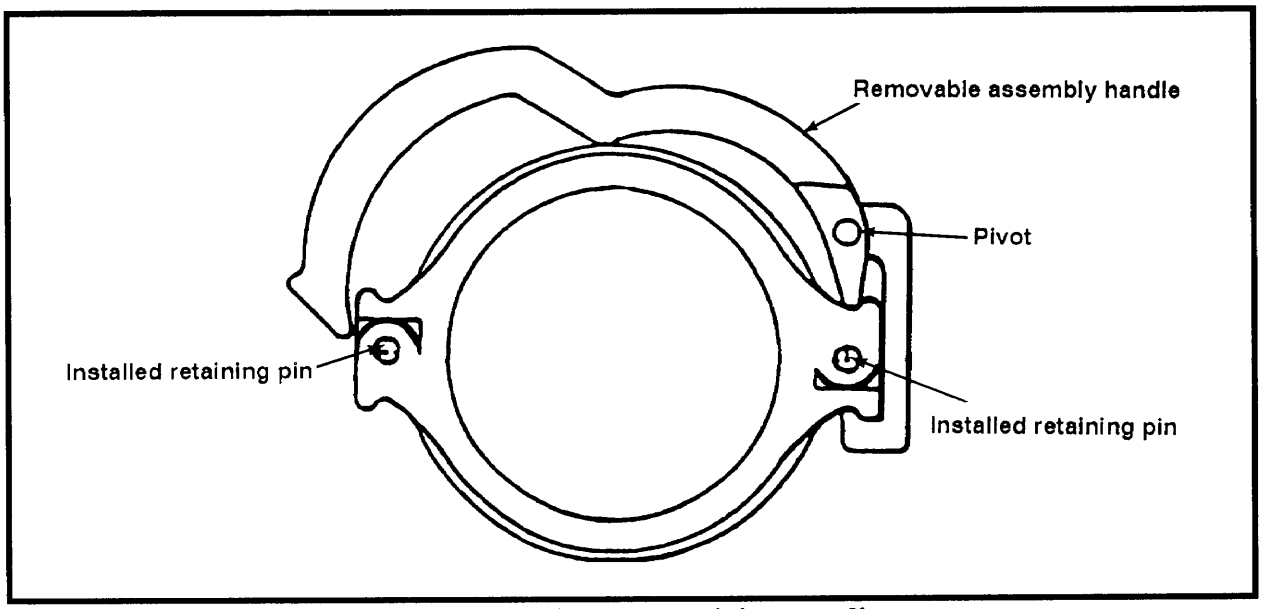


Figure 2-3. Hinged snap-joint coupling

c. *Pipeline Valves.* These valves are used in pipelines to cut off, control, and direct the fuel flow in the line.

(1) Gate Valve. This valve has a gate (disc or wedge) that is opened or closed to control fuel flow. A gate valve is used to stop flow at the tank or in the pipeline. Valves are located along the pipeline (one-mile intervals), at the bottom of long slopes, and on both sides of a stream or road crossing, so that when leaks occur, the valves can be closed to prevent excessive fuel loss and allow for repairs. A gate valve--

- Is supplied with threaded ends or with flanged ends and flange-to-groove adapters or is made up in 20-foot gate-valve sections.
- Must open to the full diameter of the pipe if used in the line and at the entrance and exit of manifold scraper stations.
- Is set, when in use, at FULLY OPEN or FULLY CLOSED, since it is not suitable for throttling the fuel flow. If the gate protrudes partially into the pipe, it may be so abraded by dirt and scale in the fuel flow that it will no longer serve as a tight valve when closed.
- Is either a rising- or nonrising-stem type with an outside screw and yoke.

In the rising-stem type (Figure 2-4, page 2-4), the upper part of the stem is threaded. A nut, fastened to the handwheel and held in the yoke by thrust collars, moves the stem as the handwheel is turned. Determining if a rising-stem valve is open or shut is easy. Therefore, this type of valve

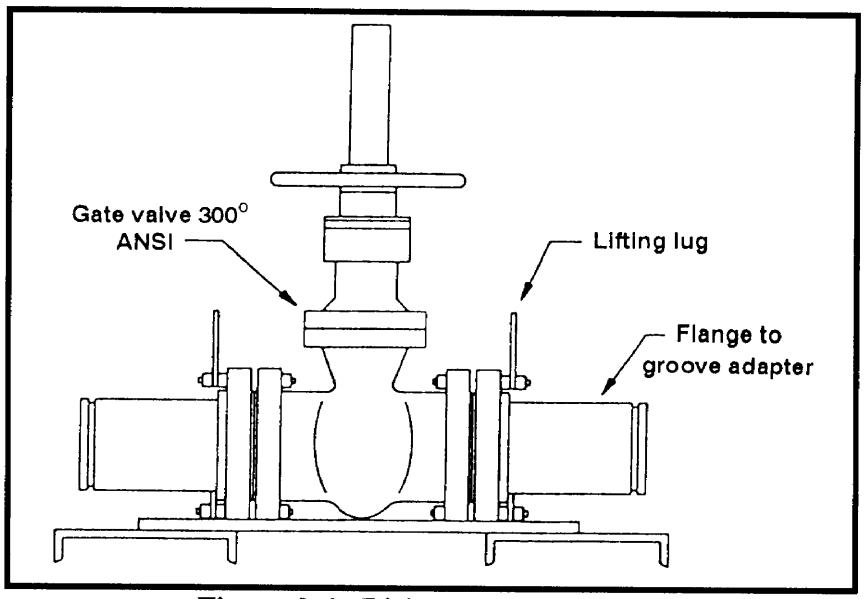


Figure 2-4. Rising-stem gate valve

is used in pipeline station manifolds and similar locations where it is necessary to identify quickly if a valve is open or closed. However, a rising-stem valve requires more space and is more susceptible to tampering or sabotage than the nonrising type. In manifold systems, a rising-stem valve is included in gate valve sections with an overall length of 36 inches.

In the nonrising-stem valve (Figure 2-5), the lower end of the stem is threaded; it screws into the disk. The disk moves up or down while a thrust collar keeps the stem in place. In both valve types, the line-closing element is made up of two disks separated by a split wedge. As the stem is turned to close the valve, the disks move down until they are directly opposite the port.

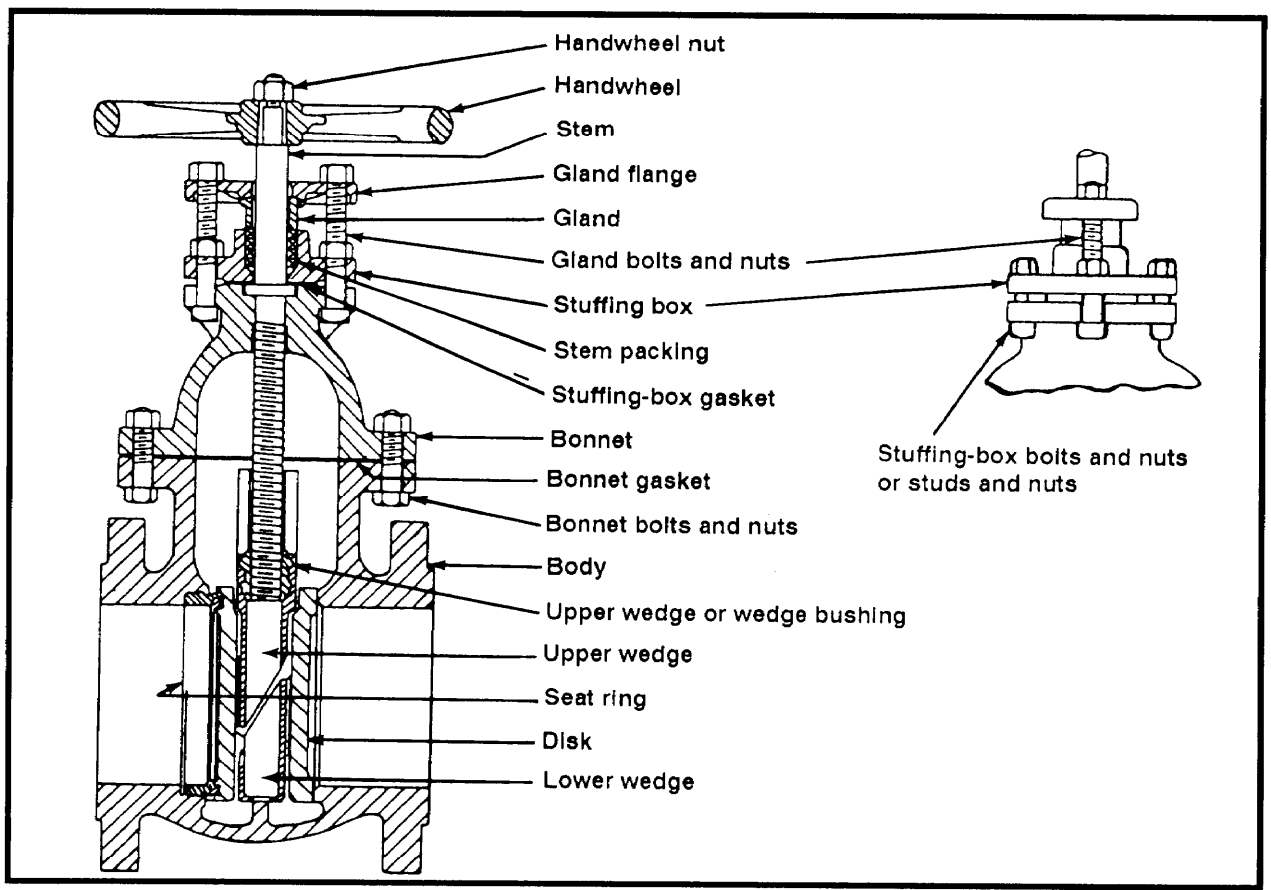


Figure 2-5. Nonrising-stem gate valve

The action of the beveled surfaces between the two disks forces the disks apart squarely against their seal and eliminates sliding action on the valve seal.

(2) Check Valve. A check valve is constructed so the fuel flows only one way. The valve has a hinged disk or clapper that the fuel pushes when the flow is in the correct direction. When the flow stops and back pressure develops, the clapper is pushed against its seat, stopping back flow. Figure 2-6 shows a typical check valve. A check valve is often used at the foot of an upgrade slope in lieu of a gate valve. So line scrapers can pass, a check valve must be opened to the full diameter of the pipe when used in the line between pumping stations.

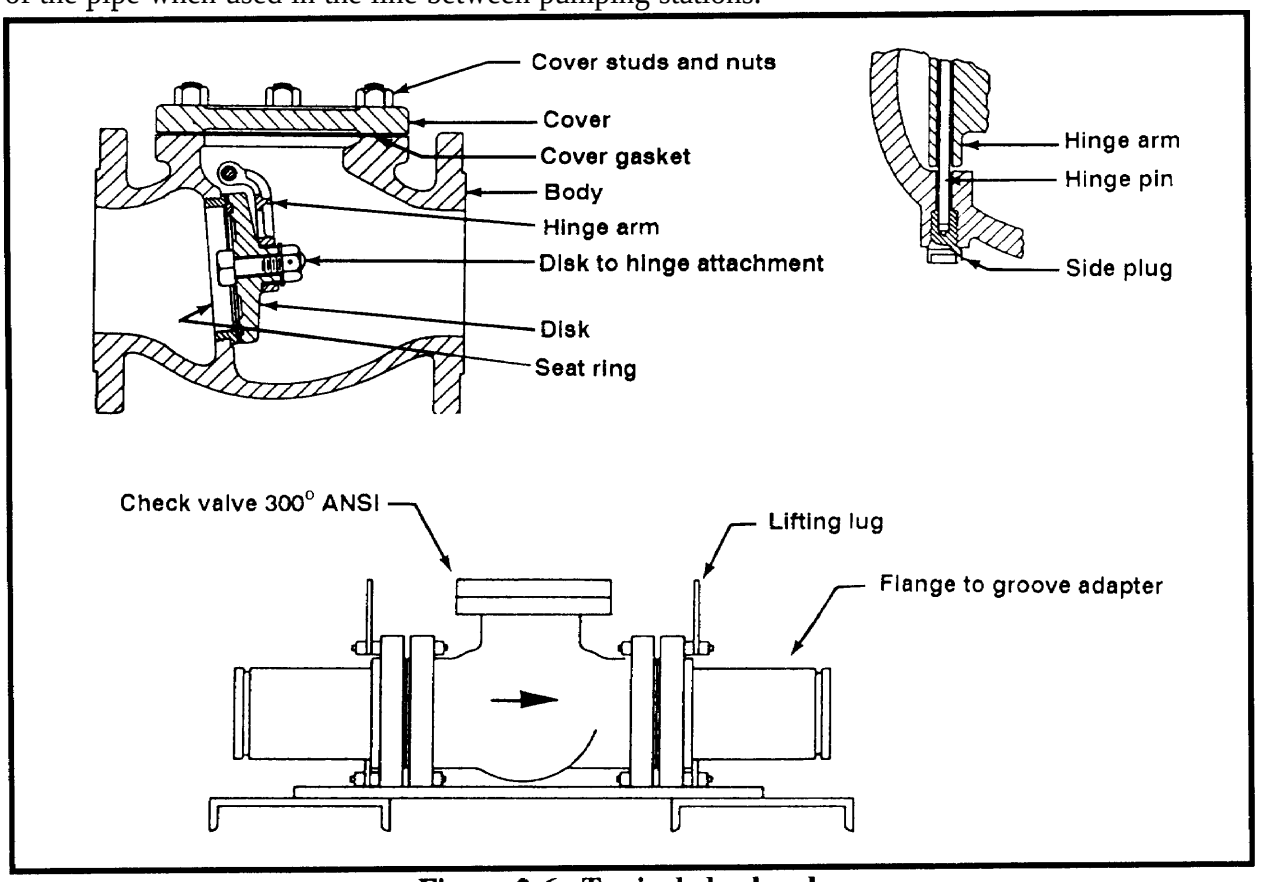


Figure 2-6. Typical check valve

(3) Plug Valve. This valve has a revolving plug with an opening so that fuel flows when the opening is aligned with the pipe. Figure 2-7 (page 2-6) shows the structure of a typical lubricated plug valve. A plug valve opens or closes with a quarter turn of the plug. When the wrench is in place, it is easy to determine if the valve is open or closed. A plug valve is used in a tank farm manifold and on launchers and receivers where quick and positive closing of the valves is essential.

A plug-valve assembly, with an overall length of 36 inches, is included in a manifold assembly. If a pumping-station manifold is assembled in the field using available material and a rising-stem gate valve is not available, a plug valve may be substituted. However, some plug valves (not in the AFCS) have openings equal to the full diameter of the pipe, while others do not. The valves that do not have full openings cannot be used in sections of the pipeline or manifold that require pipeline scrapers to pass.

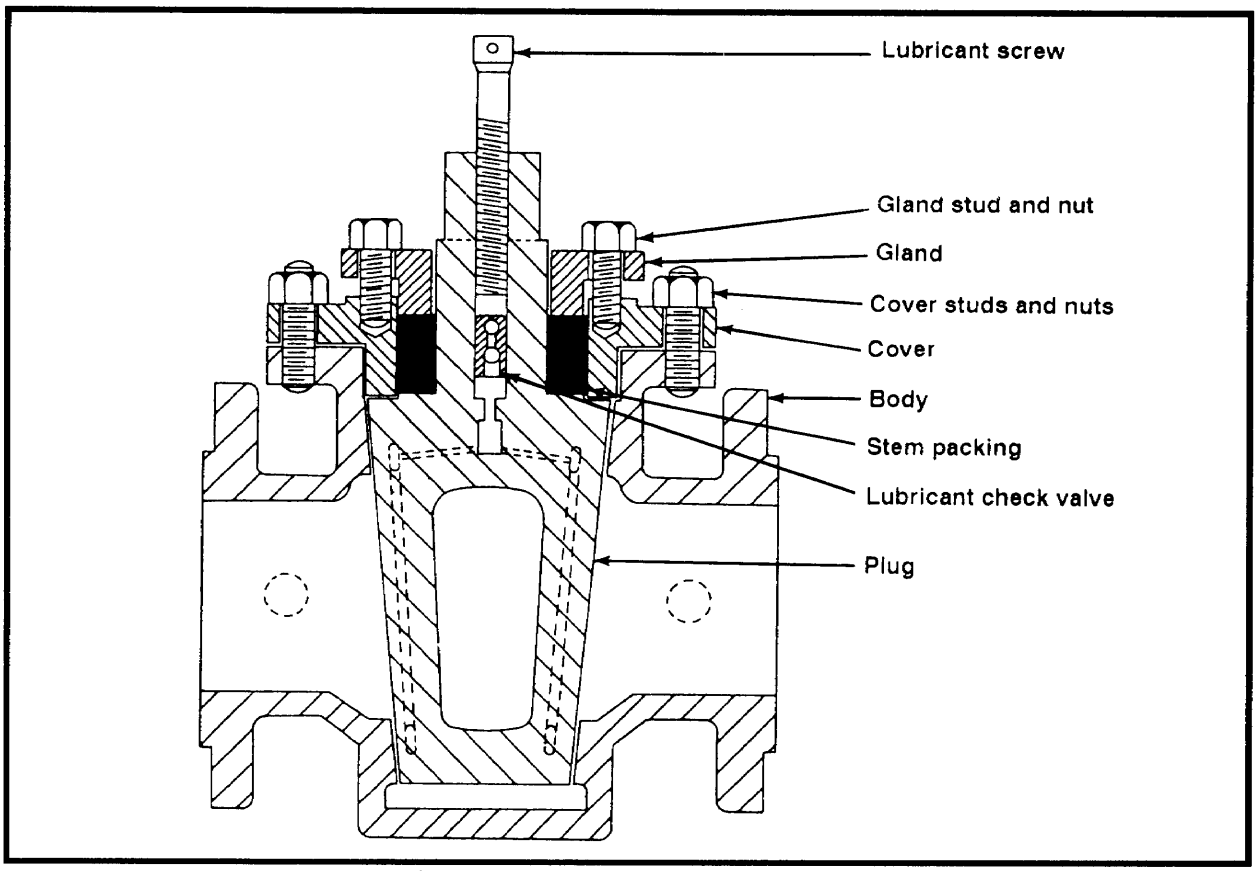


Figure 2-7. Lubricated plug valve

Since the plug fits the valve seat snugly to close the line completely, a great deal of friction results. The plug valve is lubricated with a viscous lubricant that is forced into-all parts of the valve by compressing the screw on top of the valve. The primary function of the lubricant is to jack or raise the plug off the seat and to seal the space between the plug and the seat after the plug has been turned and seats itself. This lubricant is insoluble in petroleum products but is soluble in water. Relubricate the valve whenever water passes through it. Make sure that the thick lubricant is free of dirt, grit, and other foreign matter that could obstruct lubricating channels and damage the valve seat and face.

(4) Pressure-Reducing Valve. This valve is a diaphragm-activated, spring-loaded regulator. When a pipeline is on a long, downgrade slope that is steeper than the hydraulic gradient of the line permits, the valve is spring-loaded to close. This should prevent excessive line pressure from building up when flow is stopped. Pressure- reduction regulators are included in standard pressure-reducing stations.

(5) Thermal-Relief Valve. This valve is used to relieve pressure buildup within the pipeline from the thermal expansion of the product within the pipeline. Under blocked-in conditions, overpressure can result in damage to the equipment, possible personal injury, and fire. If properly installed, the thermal-relief valve discharges small quantities of fuel through the drain hose to relieve the pipeline of pressure buildup. Thermal-relief valves are set 10 percent above the maximum pipeline pressure. The valve is located on the launcher and receiver assembly. The thermal-relief

valve should be removed, serviced, and tested routinely or every six months. Immediately install a replacement after removing a thermal-relief valve for testing or maintenance. To adjust the set pressure accurately, use the deadweight tester.

(6) Pipeline Vent Assembly. This assembly is made up of a 1-foot-long section of steel pipe that is grooved on both ends to receive the single-grooved coupling clamp (Figure 2-8). The assembly has a 3/4-inch vent tube with a 3/4-inch ball valve. A vent assembly is installed at high points to vent air from the system. It can also be installed as a low-point drain.

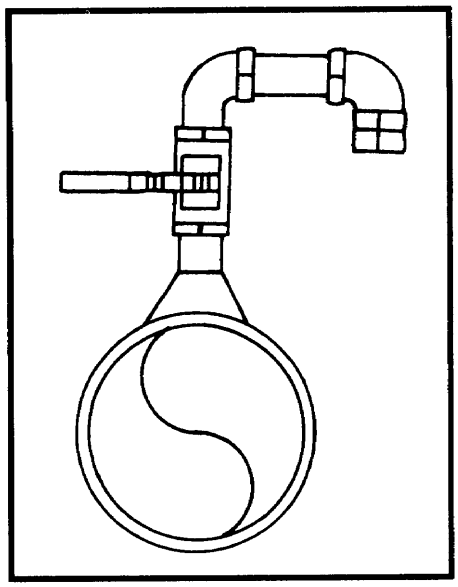


Figure 2-8. Pipeline vent assembly

(7) Pressure-Regulating Valve (Figure 2-9). This valve--

- Is used to control pressure.
- Is used at the end of line (EOL) and at the TPT intake.

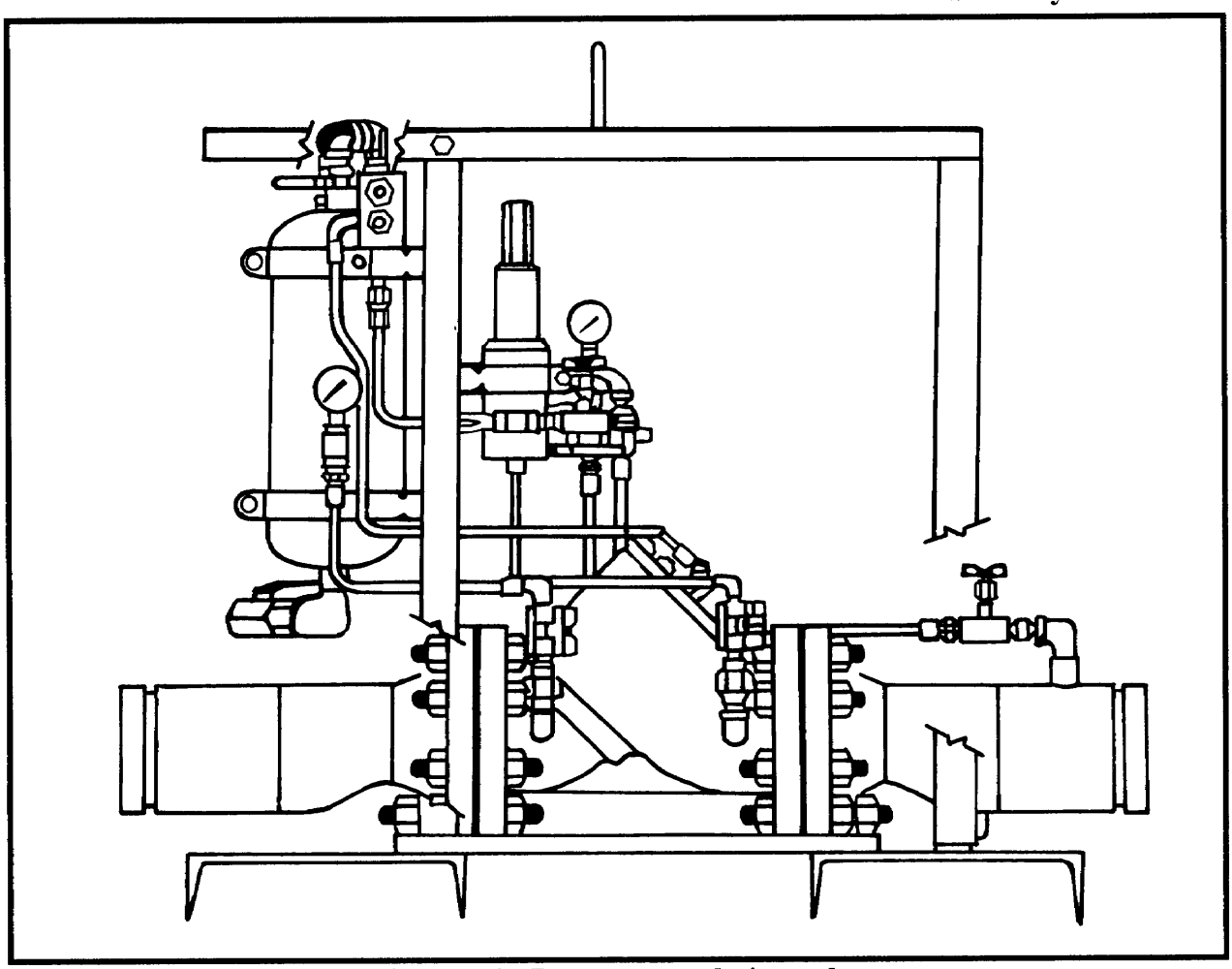


Figure 2-9. Pressure-regulating valve

- Limits the pressure into the TPT switching manifold to below 125 psi.
- Maintains a line pressure of 50 psi or above in operation and 50 psi on shutdown.
- Will not open unless the upstream pressure is 50 psi or above.
- Is supplied as part of switching manifold.

(8) Ball Valve. This valve (Figure 2-10) is used in switching manifolds to regulate the flow of fuel. The ball valve is not used in mainline pipe systems because scrapers cannot pass through them. Replace the packing in the valve when it is too compressed to lubricate the valve adequately and tightening the packing nut no longer stops a leak around the valve stern. Use graphite rings in the packing plan.

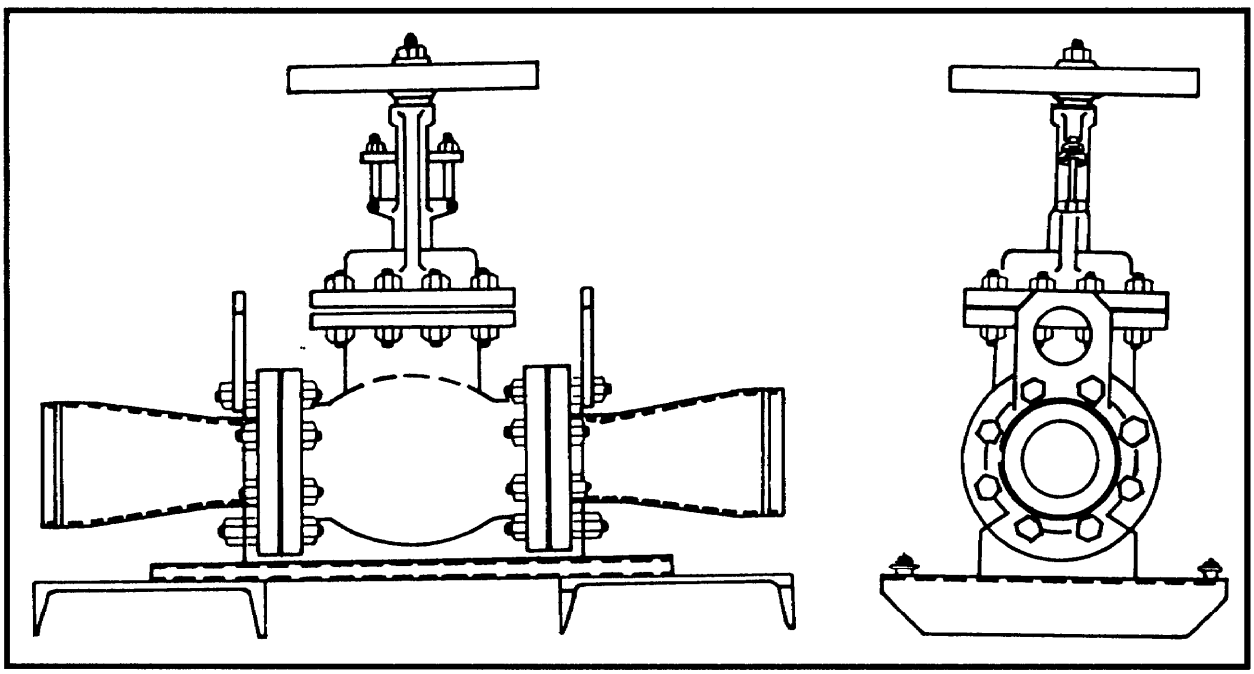


Figure 2-10. Ball valve

(9) Pressure-Control Valve (30 psi). This valve (Figure 2-11) is a back-pressure relief/regulator. The back-pressure controllers are installed in the recirculating hose lines from the fuel-dispensing assembly back to the tankage to maintain dispensing pressure of 30 psi (maximum). The valve is supplied as part of the fuel-dispensing assembly.

(10) Pressure-Control Valve (5 psi). This is a l/2-inch valve assembly (Figure 2-12). The valve is part of the two 1/2-inch dispensing points of the fuel-dispensing assembly, designated primarily for filling nonvented drums. The valve is supplied as part of the fuel-dispensing assembly.

(11) Launcher and Receiver Assemblies. These assemblies are skid-mounted and are supplied with the IPDS for use in a scraper operation (Figure 2-13). Their function is essentially the same as the cleaner barrels. However, because these assemblies are preassembled with valves and scraper passage signals and are skid-mounted, they are more readily installed and simpler to operate and maintain. Currently, only a 6-inch design is available. Other sizes can be designed and manufactured. In an IPDS pipeline, a launcher assembly is installed immediately downstream of

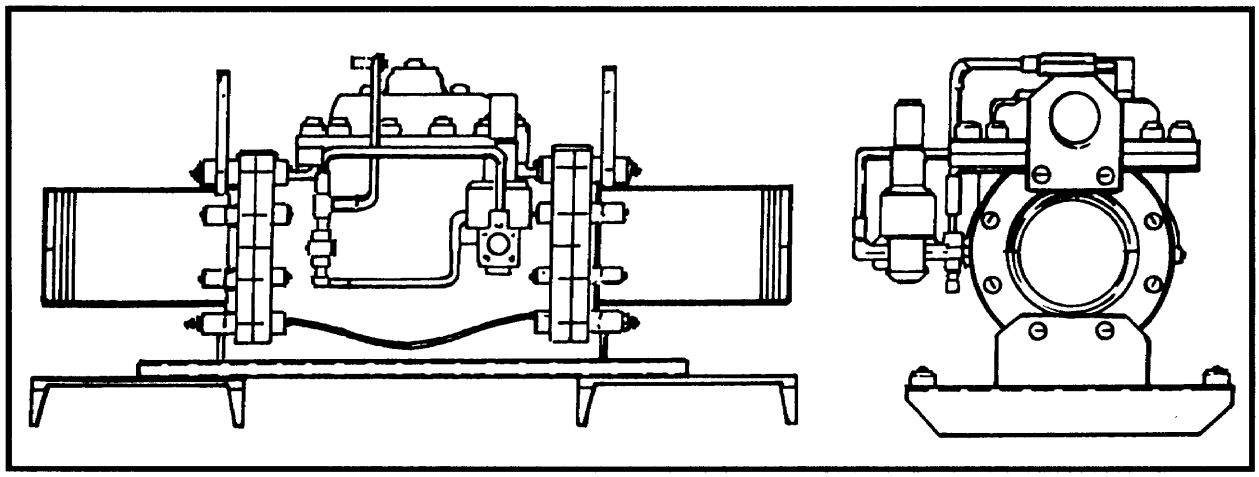


Figure 2-11. Pressure-control valve (6-inch)

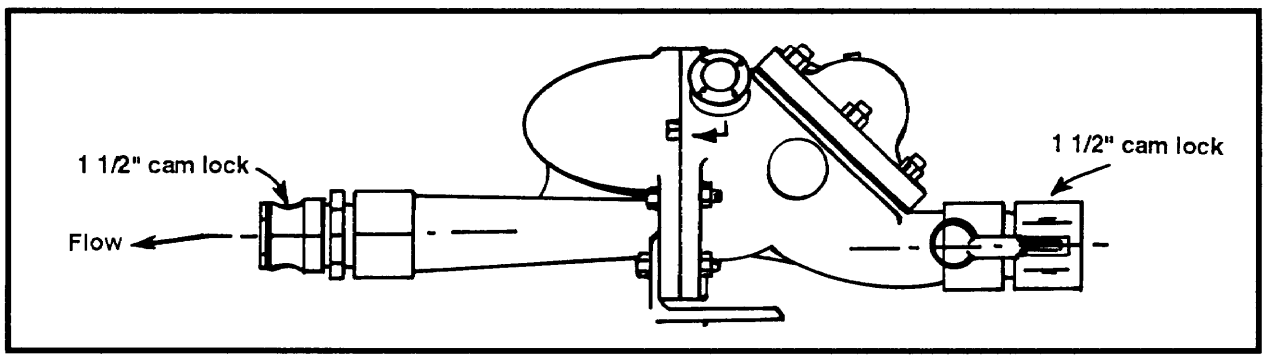


Figure 2-12. Pressure-control valve (1/2-inch)

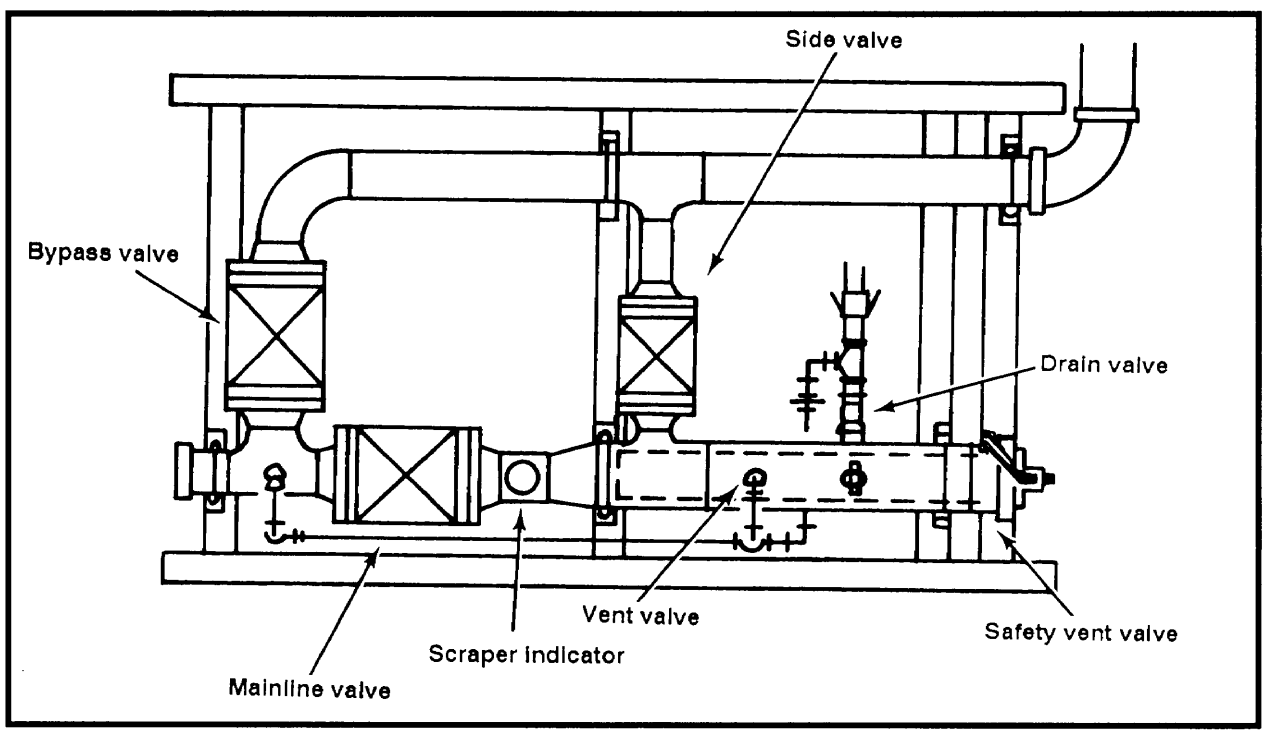


Figure 2-13. Scraper-receiver assembly

each pumping station. A receiver assembly is installed upstream of each pumping station and at the end of the line. This permits the controlled launching and receiving of scrapers (cleaners or pigs) in each pipeline segment for purging and cleaning the line as well as phase separation in certain operations.

(12) Pipeline Strainer Assembly. This assembly consists of skid-mounted dual strainers and associated valves and piping (Figure 2-1 4). The assembly is supplied with the IPDS for installation in the pipeline pumping stations upstream of the pumps. The strainers collect dirt, sand, or other debris that may be in the system to protect the multistage pumps. The dual strainer installation allows for continuous protection even if one strainer is being cleaned or repaired. The 6-inch pipe ends on the unit can be coupled to the 6-inch IPDS piping system.

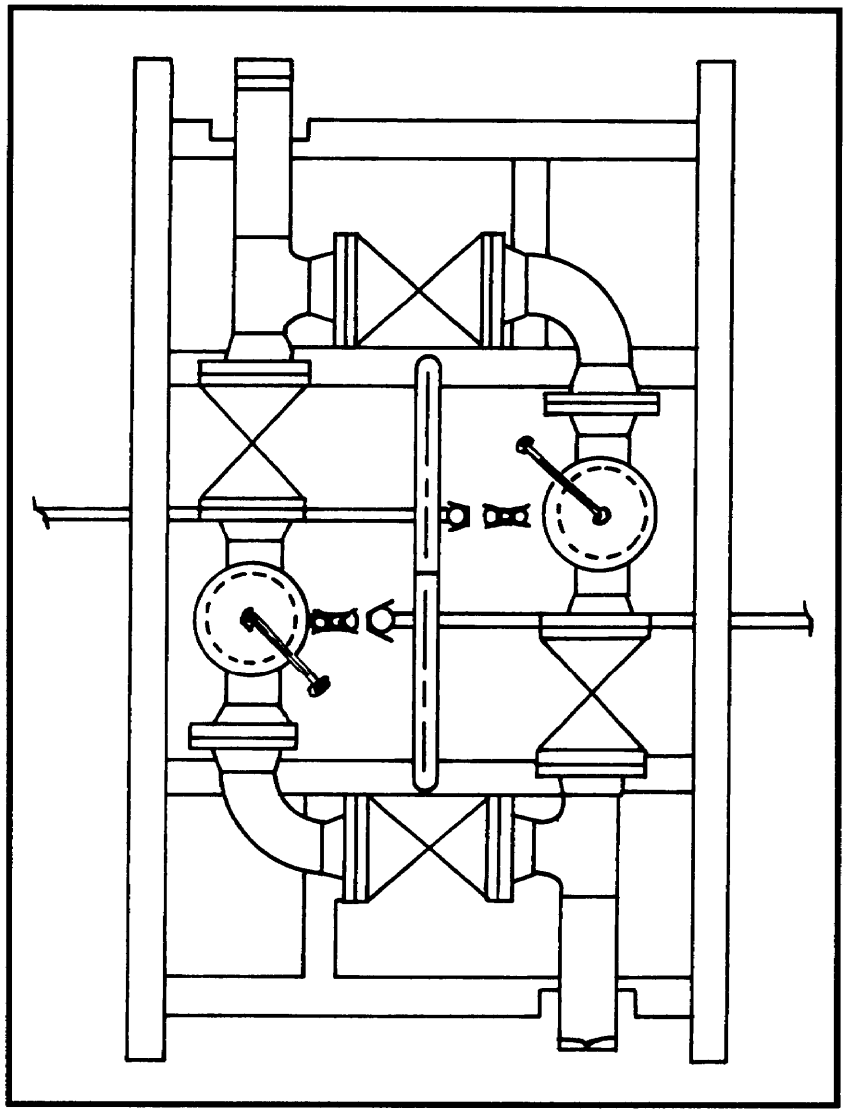


Figure 2-14. Strainer assembly

d. *Pumps.* Pipeline pumps consist of one or more impellers mounted on a rapidly rotating shaft. Liquid enters the impeller at the center and is impelled outward by centrifugal force into the volute of the pumping casing. The volute catches the discharge and converts peripheral velocity into head pressure while conducting the liquid at a reduced flow rate to the discharge nozzle of the pump casing. See the manufacturer's manual for operation and maintenance for each pump. Different pump units exist for an aluminum pipeline system and a steel pipeline system. Performance characteristic charts or curves for the pump units are in Appendix C.

(1) 6-Inch, 3-Stage, 800-GPM Mainline Pump (IPDS) (Figure 2-15). This is a skid-mounted, diesel-engine-driven, centrifugal pump with an operational output of 800 GPM at 1,800 feet of head when pumping liquids with a specific gravity of 0.85. This rated capacity is delivered when any axis of the pumping assembly is positioned at any angle up to 5 degrees from the horizontal. The pumping assembly is suitable for operation at design capacity and head from -25°F to +135°F and

at any alititude from sea level to 9,000 feet above sea level at an ambient condition of 100°F. It is used as a booster pump on the IPDS pipeline.

(2) 6-Inch, Single-Stage, Self-Priming Pump (600- and 1,250-GPM). This is a diesel-engine-driven, air-cooled, self-priming, centrifugal pump. Two models of this pump are available. The 600-GPM model (Figure 2-16, page 2-12), intended for hose-line use within terminals, is wheel-mounted and can operate in the automatic-discharge, pressure-control mode if the suction pressure is greater than 2 psi. The 1,250-GPM skid-mounted model (Figure 2-17, page 2-13) can only be operated in the manual mode. It is intended for flood, transfer, and general utility service. The rated capacity is delivered when the assembly is positioned at any angle up to 15 deprees from the horizontal. Prime is established within 2 minutes on a 10-foot suction lift after initially falling the pump casing. The pump unit has the capacity to pump petroleum products or potable water. Potable water should not be pumped after the pump has been contaminated by pumping petroleum products.

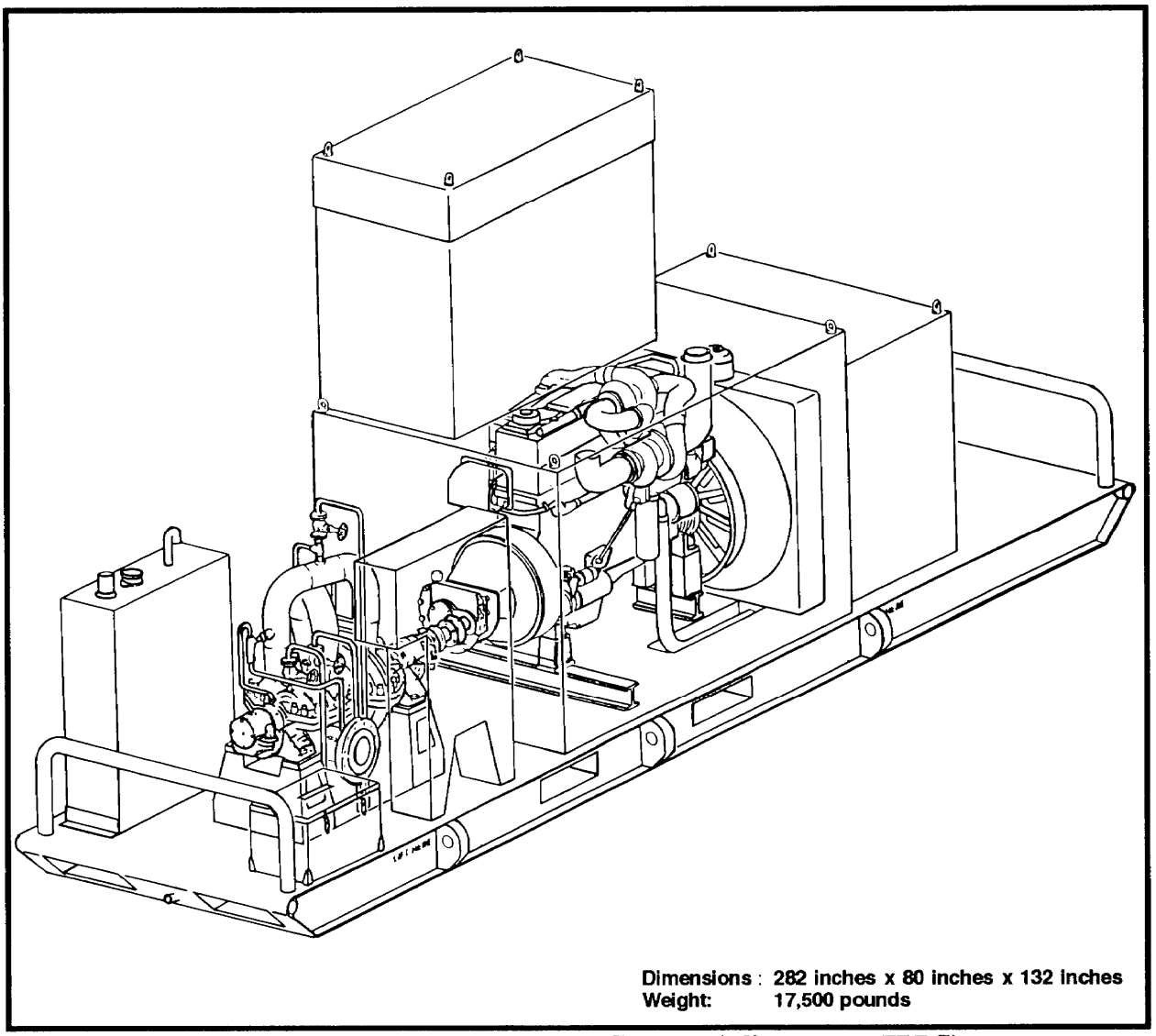


Figure 2-15. 6-inch, 3-stage, 800-GPM mainline pump (IPDS)

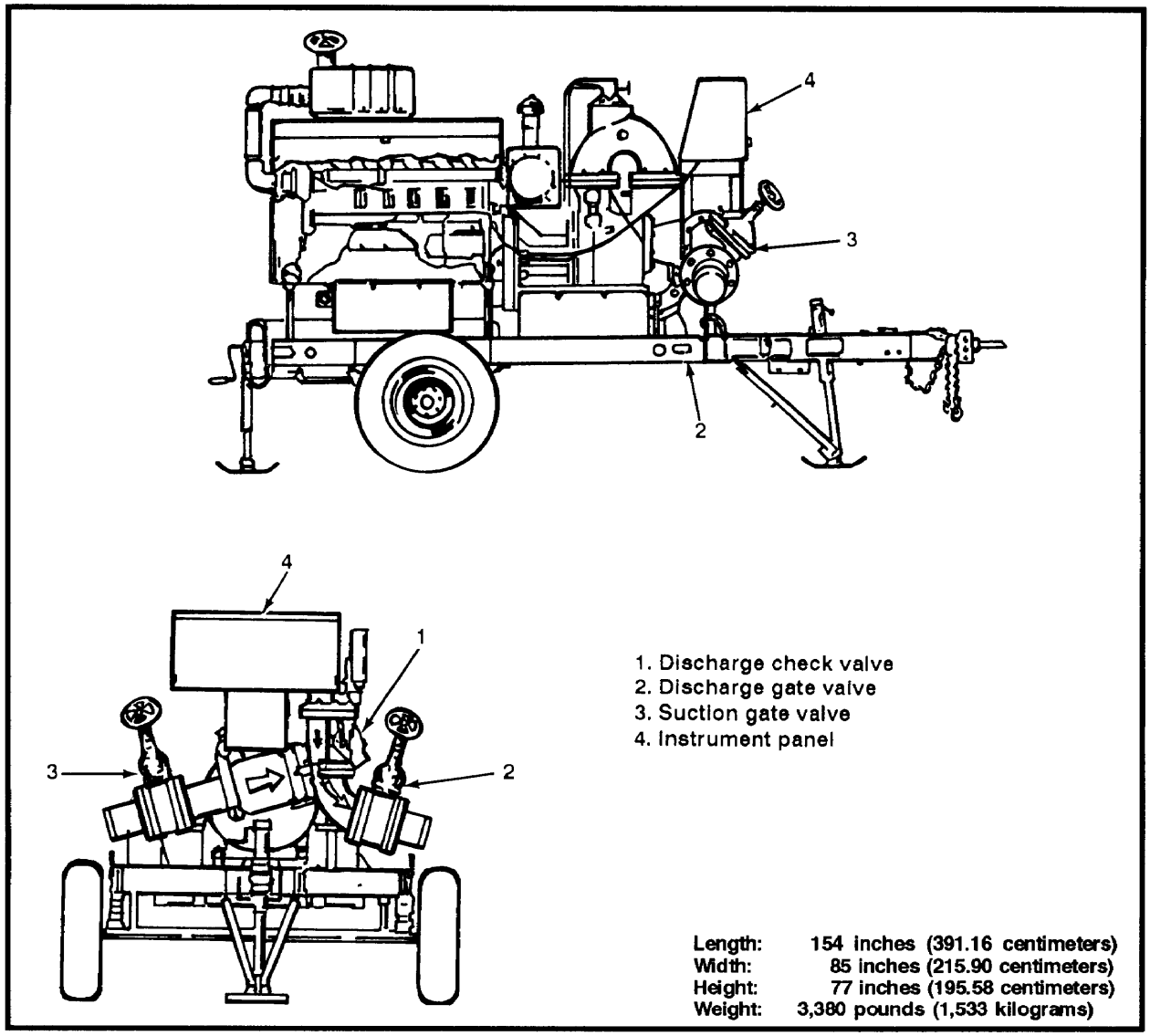


Figure 2-16. 6-inch, single-stage, wheel-mounted pump (600-GPM)

e. *Miscellaneous Pipeline Equipment.*

(l) Pipe Fittings. Standard, groove-type pipe fittings include elbows and Ts. Figure 2-18 (page 2-14) shows some of these fittings.

NOTE: Due to a maximum allowable deflection between joints of aluminum pipe of 2 degrees, elbows must be used to change direction.

(2) Pipe-Repair Accessories.

(a) Leak-repair clamps. These are specially designed clamps used to repair leaking pipes or couplings, temporarily. The split-leak clamp (Figure 2-19, page 2-14) consists of a saddle, a gasket, and stirrups that fit around the pipe where it leaks. An overcoupling-leak clamp (Figure 2-20, page 2-15) comes in two halves and covers a leaking coupling.

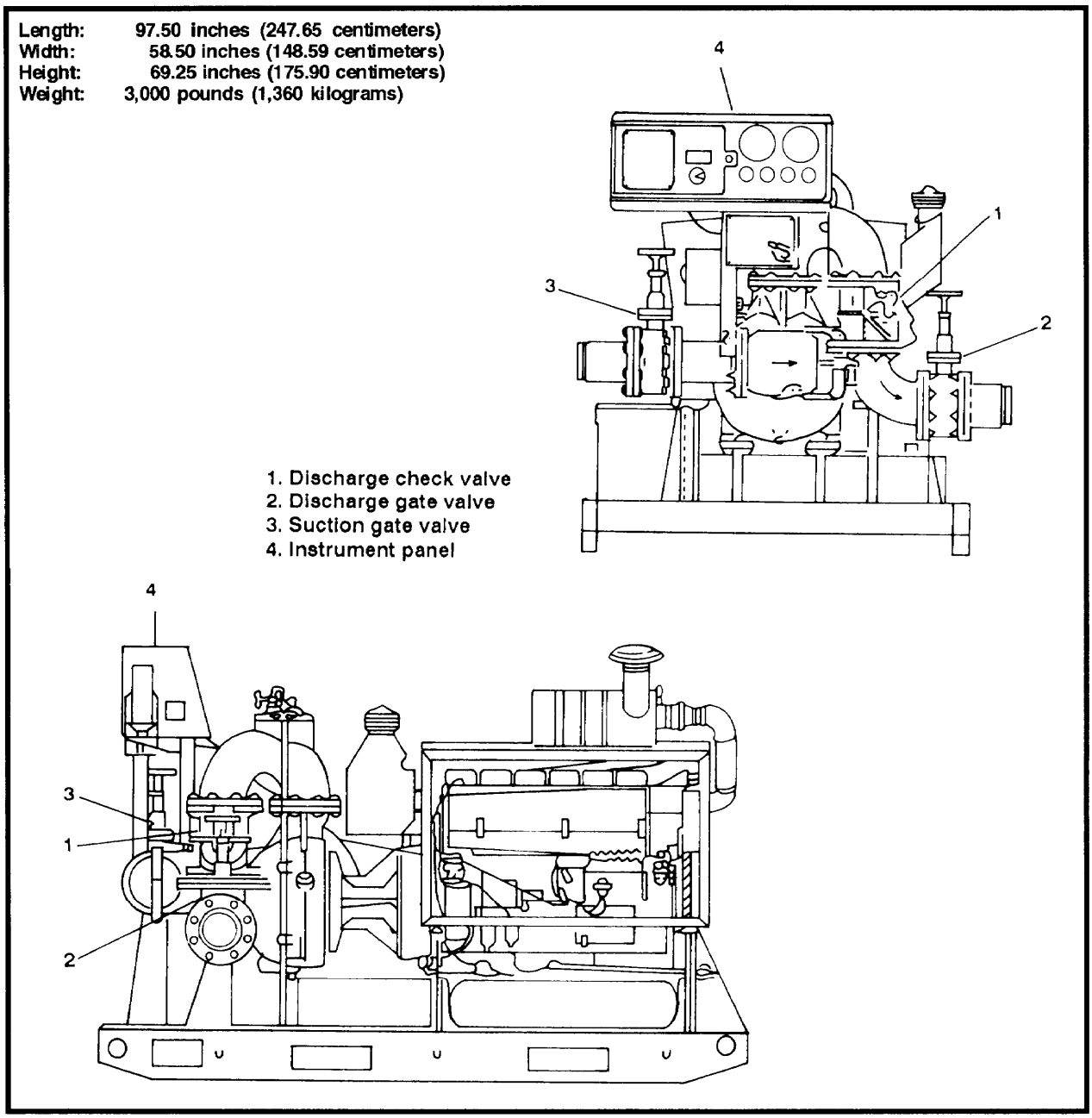


Figure 2-17. 6-inch, single-stage, skid-mounted pump (1,250-GPM)

(b) Pup joints. Pup joints are 9 l/2-foot pipe sections with grooved ends and a constant wall thickness of 0.4 inch. These joints are used to make short pieces of pipe, or nipples, and can be cut and regrooved to close gaps less than 19 feet in newly constructed or broken pipelines and in pumping-station manifolding. Repair crews sometimes carry pup joints of assorted lengths. When a damaged section is removed (especially a surface-laid, grooved-coupled-type pipeline), the two ends are likely to spring apart. This occurs most often on long downhill slopes during very cold weather because of pipe contraction. The gap is likely to be 1 or 2 inches longer than the standard 19-foot length of grooved pipe section.

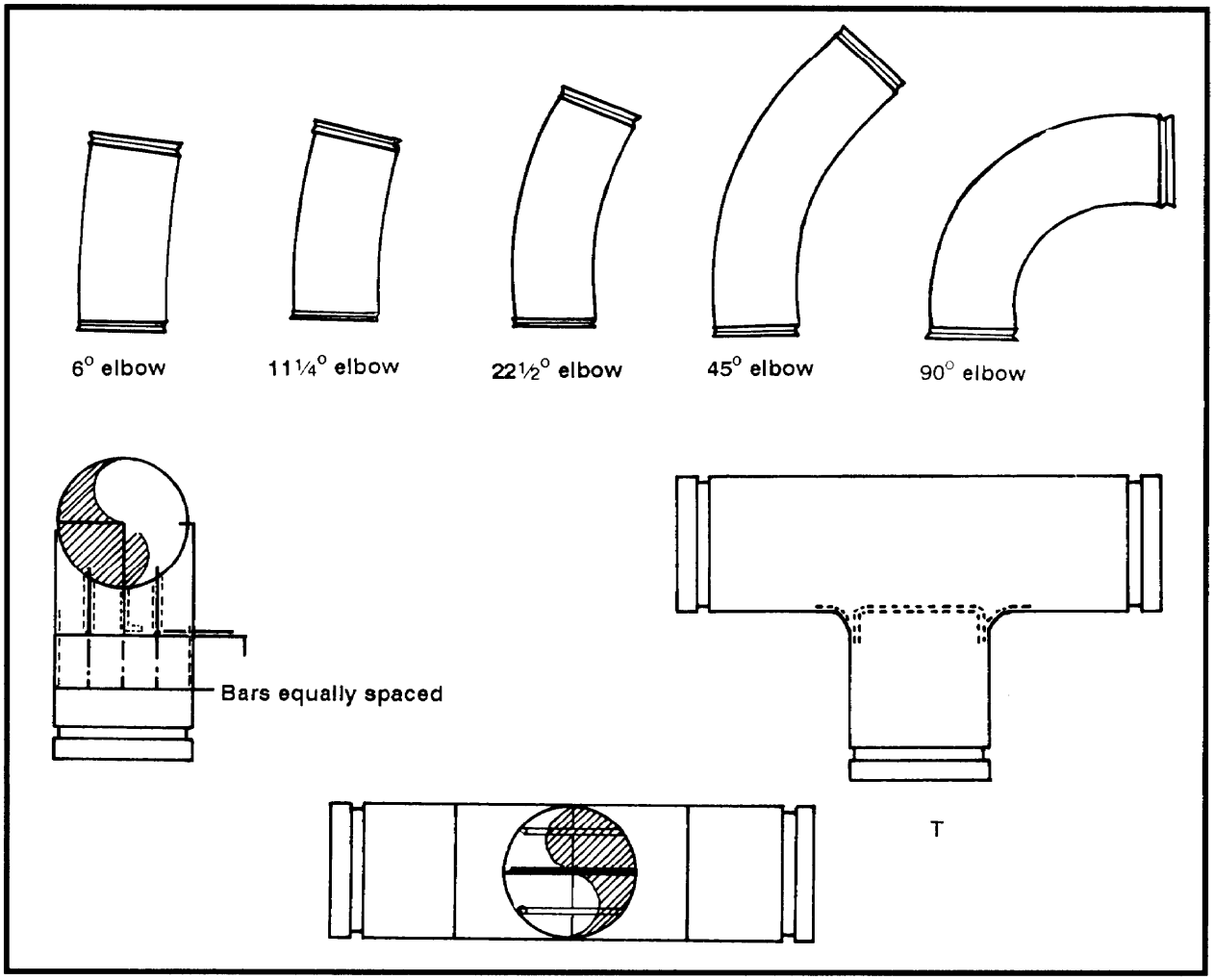


Figure 2-18. Pipe fittings for aluminum pipe

(3) Culvert Pipe. This is standard, nestable, steel corrugated pipe used for protecting pipelines located under roadways to minimize damage from the weight of passing vehicles. Culvert pipes come in 24-inch-long sections that are 12, 18, and 24 inches in diameter. The 12- and 18-inch pipes are 16 gauge; the 24-inch is 14 gauge.

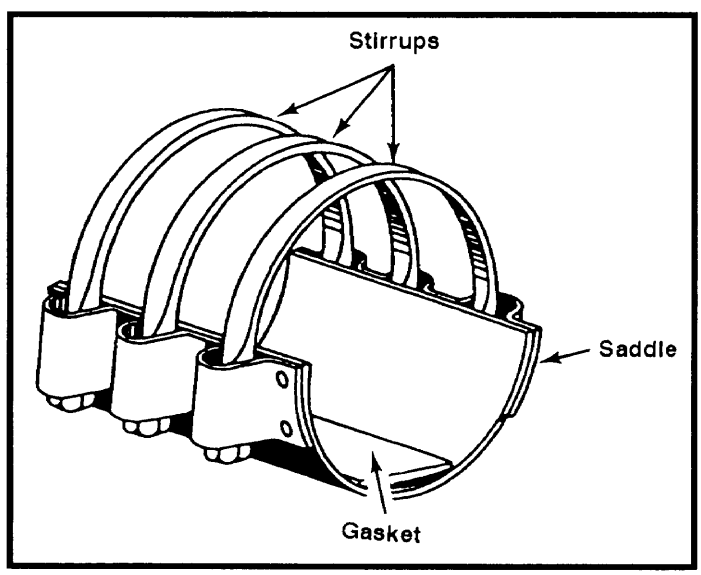


Figure 2-19. Split-leak clamp

2-4. Specialized Pipeline Tools and Equipment Pioneer hand tools and standard table(s) of organization and equipment (TOE) earth-moving equipment are used to clear and level the right-of-way for pipelines and to prepare

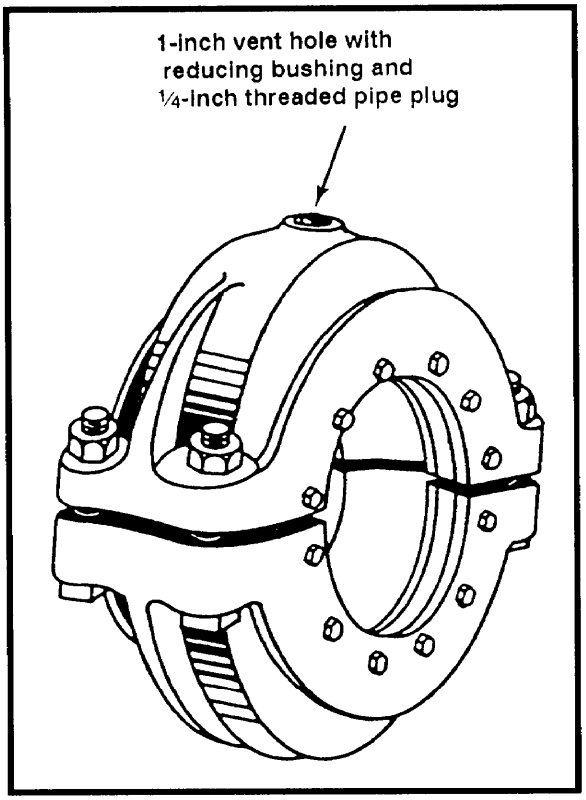


Figure 2-20 Overcoupling-leak clamp

pumping station and tank-farm sites. The pipeline construction support company has limited earth-moving equipment but does have pioneer hand tools. Specialized equipment, assigned to the pipeline support company, is required for handling, placing, and installing valves, pumps, and pipeline anchors. This pipeline engineer company's primary mission is to support the engineer battalion in the construction and rehabilitation petroleum pipeline systems and facilities.

a. *Tools.*

(1) Hydraulic Drivehead Kit. The hydraulic drivehead is used to install pipeline anchors midway between the expansion devices along an aluminum pipeline system. A clamp is installed around the pipe and fastened to the anchor shaft, which is augured into the ground. The rotation rate is from 0 to 21 revolutions per minute (RPM). The anchors are also used in the construction of suspension bridges and pumping-station protective shelters. The hydraulic drivehead kit consists of a hydraulic motor and anchor adapter, which can be mounted on a JD410 or a SEE dipper stick after the bucket is removed. The drivehead takes about 30 minutes to install.

(2) Aluminum Pipe Section (Pup), 9 1/2 Feet. These are alloy, constant-wall pipe sections that come in frame bundles of 25 each (Figure 2-21). The pipe sections are used in the pumping stations, at the end of the pipeline, and at other points in the pipeline, as required for makeup. The sections can be cut to any required length and regrooved, using the supplied grooving and cutting equipment. The sections are standard with the 5-mile pipeline sets.

(3) Cutting, Grooving, and Beveling Machine (IPDS). This is a portable machine used to cut and groove nonstandard lengths of aluminum or steel pipe. This machine can also be used to bevel steel pipe for welding. The kit is made up of two large suitcases and two pipe stands. The machine

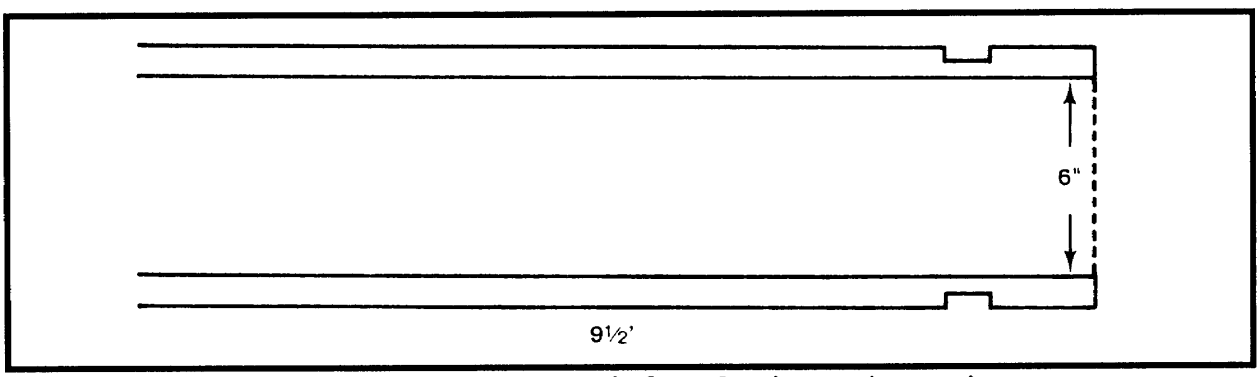


Figure 2-21. 6-inch by 9 1/2-foot aluminum pipe section

is powered by a 250-cubic-foot-per-minute (cfm) air compressor or by a generator. It is used primarily for cutting and grooving pup joints required during mainline pumping-station construction. The pup joints are normally precut but can be cut on location. It takes about 30 minutes to cut and groove each end of pipe.

(4) Pipeline-Construction, Grooved-Coupling, Steel-Tubing Set. This set contains the tools and equipment needed to construct and maintain steel-coupled-type pipelines and pumping-station manifolds. The set consists of three chests that contain crowbars, shovels, brushes, files, rules, steel tapes, wrenches, lineup cages, and pipe-cleaning swabs needed to equip four pipeline-coupling crews and two pumping-station construction crews or six pipeline-coupling crews simultaneously.

(5) Supplemental Pipeline-Pumping-Station Set. This set supplements the general mechanic's tool set. It contains all of the tools required for operator maintenance and repair of the standard pumping units and the 4-, 6-, and 8-inch pumping-station manifolds. The set contains--

- Special pin removers and a special gooseneck-type screwdriver for removing pins in the coupling between pump engines and pumps.
- Locking pliers for removing pump seals.
- A thin adjustable wrench for backing up valve flange nuts between the flange and body of manifold valves.
- Box wrenches and open-end wrenches for removing and tightening pump-casing nuts and bolts.
- Pipe wrenches for maintenance of small-threaded pipes.
- Allen set-screw wrenches for removing and installing pump seals and coupling pins.
- Tappet wrenches for adjusting pumping engine valves.
- A socket-wrench handle and wrench sockets to fit all grooved-type coupling nuts in the 4-, 6-, and 8-inch pumping-station manifolds.

(6) Pipe-Fitter's General Tool Kit. This kit contains a variety of hand tools required for all types of pipe-fitting work on 1/8- to 2-inch pipe. The kit includes--

- A pipe cutter, die-head thread cutter, receding-segmental thread cutter, and hacksaw.
- A machinist's hammer, slip-point pliers, folding rule, screwdriver, and pipe vise.
- Various size pipe wrenches.

(7) Pipe-Fitter's Supplemental Tool Kit. This kit supplements the pipe-fitter's general tool kit. It contains a minimum of hand tools for cutting, threading, and fitting the 2 1/2- to 4-inch pipe.

(8) General Mechanic's Automotive Set. This set is an ordnance item of issue and is used primarily for minor maintenance or replacement of external accessories of pumping unit engines.

(9) Welded Steel Pipeline Construction Set.

(a) 4-,6-, and 8-inch pipe sizes. This set contains the special size equipment, in the correct quantities, required for handling the 4-, 6-, and 8-inch pipe at stockpiles, stringing pipe sections, and laying and welding the pipeline.

(b) 12-inch size. This set contains the special size equipment, in the correct quantities, required for handling, stringing, laying, aligning, and beveling 12-inch pipe.

(10) Welder's Steel Supplemental Pipeline Construction Set. This set contains the tools and equipment required for welded pipeline construction that are not in the oxyacetylene torch outfit, cutting-and-welding equipment set. The set includes equipment for aligning flanges for welding, cleaning, making pipe bevels, marking pipe for mitered fittings, and removing welding slag. The set contains an initial supply of 1/8- and 5/32-inch, reverse-polarity, direct-current, mild steel electrode needed for pipeline welding. The set also includes an umbrella that is used to keep sunlight off buffed welds while being inspected, rain off hot welds, and sunlight from entering the back of the welder's helmet. This set is essential when using any welded-pipeline tool set described in Appendix B .

b. *Equipment.*

(1) 5-Ton, Cargo Long Bed. This truck is the primary vehicle used when constructing military pipelines. It is used to pull the 4-ton bolster trailer, to transport pipe to the construction site, and to haul valves, couplings, and soldiers to and from the construction site.

(2) 4-Ton Bolster Trailer. This is a dual-axle trailer with four bolster attachments and an adjustable tow boom (Figure 2-22, page 2-1 8). The bolster trailer is the primary means for transporting pipe from construction staging areas to the construction site. Pipe or tubing sections rest on each bolster assembly and are contained by the side stakes and binder chains or straps.

(3) 40-Ton Crane. This crane is used for lifting and placing mainline pumps at construction staging areas and at pumping-station locations.

(4) 7 l/2-Ton Crane. This crane is used for lifting and placing the scraper-receiver assembly, strainer assembly, launcher assembly, and valves along the pipeline and at pumping station locations. (See Figure 2-23, page 2-19).

(5) SEE. This excavator is used to install pipeline anchors, dig and backfill culverts, and load and unload gate and check valves. (See Figure 1-4, page 1-8).

(6) 6,000- and 10,000-Pound Rough-Terrain Forklifts. These forklifts are used to load and unload pipeline components at construction staging areas along the pipeline trace. (See Figure 2-24, page 2-19).

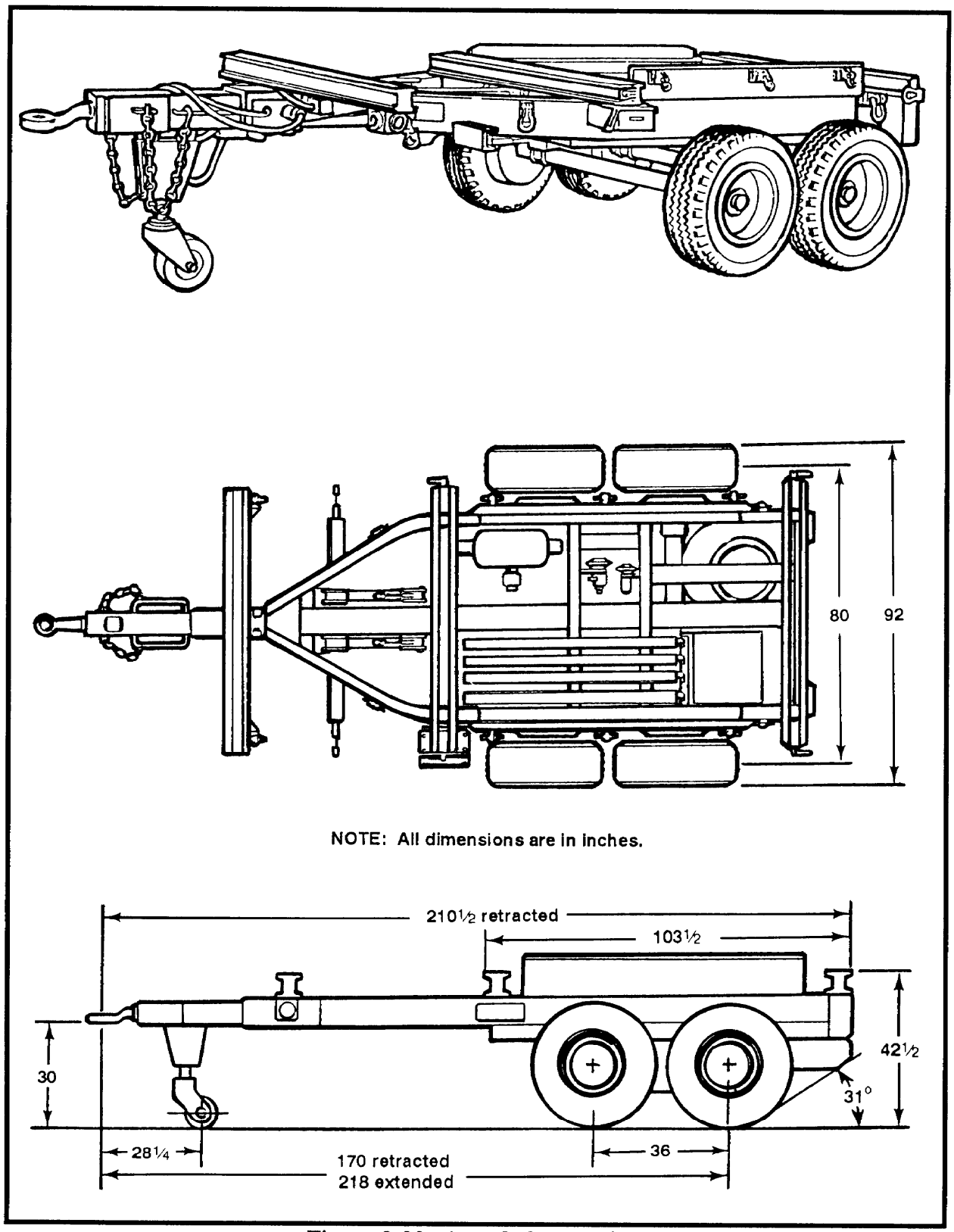


Figure 2-22. 4-ton bolster trailer

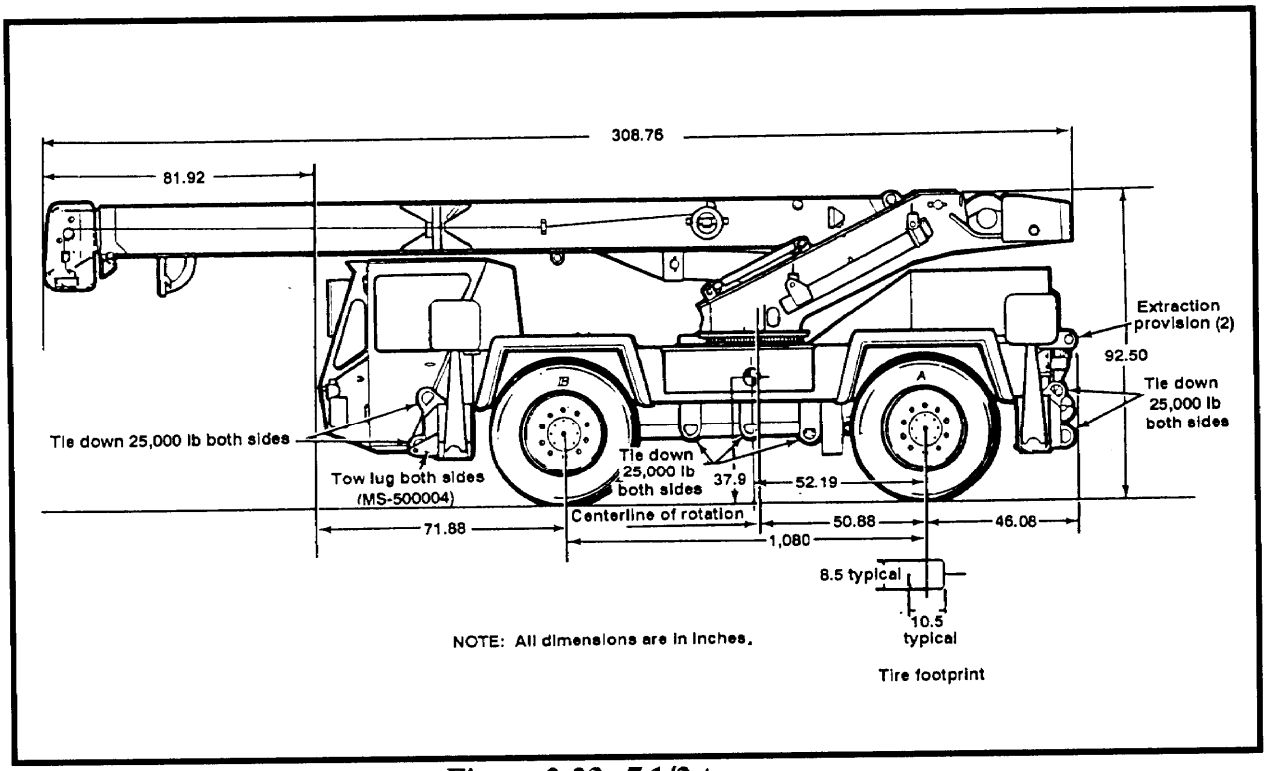


Figure 2-23. 7 1/2-ton crane

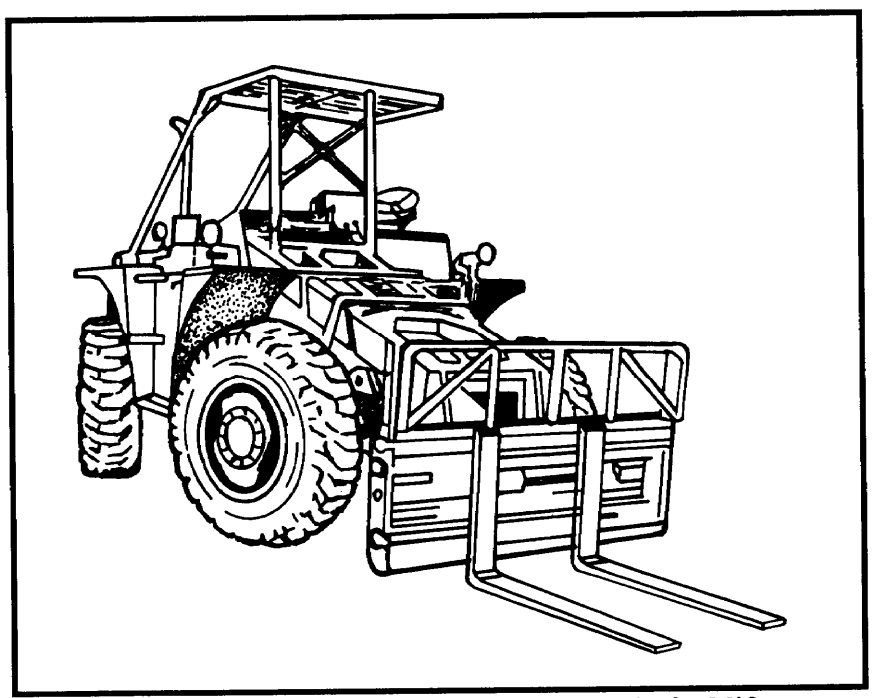


Figure 2-24. 6,000-pound rough-terrain forklift

Chapter Three. Planning for Bulk-Fuel Distribution

3-1. Introduction. Military forces require large quantities of petroleum products in support of combat operations. Special channels of responsibility for the supply of bulk-petroleum products, both in the continental United States (CONUS) and in overseas theater, have been established to ensure uninterrupted supply of these products. The Defense Logistics Agency (DLA) is responsible for the integrated management of bulk petroleum. (DLA works through the Defense Fuel Supply Center (DFSC).) DFSC procures and, with the military services and the Military Sealift Command (MS C), arranges for delivery of the products to the military services. DFSC contracts with a commercial supplier in CONUS or overseas and ensures that required fuel is shipped to the theater. Each of the military services has service control points that coordinate with DFSC on petroleum logistics matters. The US Army Petroleum Center performs this function for the Army worldwide.

3-2. Planning Organizations.

a. *Joint Petroleum Office (JPO).* The JPO, established by the Joint Chiefs of Staff, provides staff management of petroleum at the theater level on the staff of the unified commander. The JPO submits the monthly petroleum requirements of all the military services within the theater to the DFSC.

b. *Theater Army.* Theater army headquarters provides broad planning guidance for Army petroleum support. It supervises current operations and conducts long-range planning. The petroleum group, assigned to the theater army, is the major Army petroleum operator for the theater. When demand exceeds availability, the theater commander will establish an allocation system, based on priority, to support the theater plan of operations.

c. *TAMMC.* The TAMMC is the item manager for both bulk and packaged petroleum products. They collect long-range (annual) petroleum requirements for the theater that are based on the consumption data the petroleum staff officer and the petroleum group forward. The TAMMC submits petroleum requirements for the theater to the JPO.

d. *Engineer Command (ENCOM).* The ENCOM provides construction support for the petroleum facilities that are required to accomplish the theater support mission. The ENCOM plans and supervises construction or renovation of ports, roads, railways, petroleum pipelines, and petroleum-storage facilities in support of the bulk-fuel distribution system. General engineer construction units are augmented with specialized engineer units to accomplish the pipeline-construction mission. The engineer units normally assigned to the ENCOM to construct petroleum facilities are the--

- Engineer construction group. This is a flexible organization designed to command up to five engineer battalions (or their equivalent) in assigned or attached troops.
- Combat heavy engineer battalion. This is the basic unit assigned to a specific pipeline construction mission. It is augmented with specialized units for equipment, expertise, and training support.

- Engineer pipeline construction support company. This company has limited, independent capabilities to construct pipeline systems.
- Engineer port construction company. This company provides specialized equipment and expertise for an engineer group for the construction and/or repair of waterfront structures.

The task organization of the engineer units for pipeline construction is based on mission, enemy, terrain, troops, and time available (METT-T). The engineer pipeline construction unit can provide technical advisors and equipment to three company-sized elements at a density of one squad per platoon on a 24-hour basis.

3-3. Port Support Operations. When pipeline materials arrive at the port of debarkation, they should be moved quickly from the port facility to the construction staging areas. If possible, the pipeline components, which require forklifts or cranes to be moved, should be transported directly from the ship-to-ground transporters. This will alleviate inefficient use of critical lifting and loading assets by eliminating double movement of the construction materials.

Pipeline materials are bulky and require a large staging area. Ten miles of pipeline components with one pumping station occupy an area about 100 yards by 50 yards. The staging area available at the port, the down-load rate (based on the rate of construction), and the ground-transportation rate need to be calculated so the port does not become clogged with pipeline components. The port-operations unit is responsible for down loading the pipeline components. Close coordination is required between the constructing engineer unit, the transportation unit tasked to move the components, and the port-operations unit responsible for down loading the materials.

3-4. Transportation Support Requirements. Moving pipeline construction materials to staging areas along the pipeline route is an equipment-intensive operation that is key to the success of the mission. Pipeline components either are stored in the US or are pre-positioned in the TO. They are packed for all methods of transportation. Based on theater requirements, transportation planners will determine the most effective method of moving pipeline components. The most common method is to use 40-foot flatbed trucks to and from shipping ports.

To transport 10 miles of 6-inch aluminum pipeline components, twenty-five 40-foot low-bed trailers are required. An aluminum-system mainline pumping station can be loaded on four 40-foot low-bed trailers. The extra material-handling equipment assigned to the pipeline construction support company must be allocated for loading and unloading the components. From the port of embarkation (sea) to the construction staging areas, the density of equipment support required is based on the rate of construction and the available port facilities. Table 3-1 is a list of the major aluminum pipeline system (IPDS) components with shipping dimensions and weights.

NOTE: The Sierra Army Depot stores the IPDS (TPT, pipe, couplings, and other hardware) containers (156 joints of pipe per International Standards Organization (ISO) container).

3-5. Construction Staging Areas. These areas are the transfer points of components from the 40-foot low-bed trailer to the bolster trailers and the 5-ton cargo trucks. Therefore, the location, size, and operation of the staging areas are key to the success of a pipeline-construction mission. Staging areas are located about every 10 miles along the proposed pipeline route. This reduces the turnaround time required to move the components from the construction staging areas to the construction site.

Table 3-1. Aluminum pipeline components and measurements

Item	Dimensions (inches)	Weight (pounds)
Pipe, aluminum, 6-inch x 19-foot, 25 per bundle	230 x 42 x 41	3,350
Pipe, aluminum, 6-inch x 9 1/2-foot, 25 per bundle	114 x 42 x 41	2,205
Couplings, 6-inch, single-groove, 25 per box	40 x 22 x 20	630
Gate valve, 6-inch, 2 per box	48 x 42 x 45	1,488
Check valve, 6-inch, 2 per box	48 x 25 x 30	650
Elbow set, 6-inch, containing per set: 45°, 7; 22.5°, 5; 11.25°, 5; 90°, 2; 6°, 6	48 x 46 x 30	870
Pump, 800-GPM	282 x 80 x 78	17,500
Strainer asembly, 6-inch	122 x 70 x 55	4,790
Receiver assembly, 6-inch	122 x 70 x 55	3,660
Launcher assembly, 6-inch	122 x 70 x 55	3,505
Pump protective structure, 800-GPM	86 x 46 x 46	3,531

The mainline pumping unit, which requires a 20-ton crane (minimum) for loading, should be moved directly to the pump-station locations.

3-6. Pipeline Route.

a. *Considerations in Route Selection.* The pipeline route is based on the petroleum supply and the demand locations that are assigned to the ENCOM by the theater army support command. The route will determine construction time, effort, and material requirements in either a positive or negative manner. The engineer pipeline construction support company has the expertise to determine the best pipeline route from source to demand. Construction equipment access, terrain, obstacles, and pipeline trace camouflage are the key factors in determining the best construction route. Topographic units have detailed topographic information that may help personnel evaluate an area and select the best route.

(1) Construction Equipment Access. A pipeline usually follows the most direct route possible from source to demand. After considering all the variables, the pipeline route is usually the route the campaign follows. However, the route should not run along the main supply route (MSR) because it is an important military target. The pipeline route should roughly parallel secondary roads. This will enable the construction crew to execute the stringing operation of pipeline construction as quickly as possible.

The stringing operation is the most labor-intensive and time-consuming activity in military pipeline construction. A pipeline is normally laid between 20 and 50 feet from the shoulder of the road. (An alternate route may be selected if it will save in the construction, patrol, operating-personnel, security, and maintenance areas.) Often, following the route that is cleared for power lines is best because power-line routes follow the most direct route (usually a straight line). However, access for vehicles during the stringing operations could be a problem, making the power-line route unusable. Using cross-country cutoffs can be beneficial where primary roads wind

excessively and if the time and material savings are consistent with the extra construction and maintenance effort required.

(2) Terrain. The route chosen should be as level as possible, especially if it is an aluminum pipeline system. Unlevel terrain will require the use of sandbag leveling to limit joint deflection to two percent. A pipeline should be diverted around difficult terrain such as marshes, swamps, or land subject to periodic flooding.

(3) Obstacles. Obstacles can greatly increase the construction effort of a pipeline. The most common obstacle in pipeline construction is a road crossing. Existing culverts should be used whenever possible even if the pipeline must be diverted a short distance from its route. Any new road culverts that are required should be built before the pipeline reaches that culvert's location.

Culvert materials are provided in 5-mile sets of the new aluminum pipeline. Standard-weight commercial pipe can be used as culvert material, if available. The advantages to using standard-weight pipe are that it--

- Takes less soil for covering because the pipe has greater strength.
- Eliminates the need for the culvert to be constructed as with bolted culvert sections.

The disadvantage of using standard-weight pipe as a culvert is that additional transportation and placement are required.

(4) Camouflage. Based on threat type and level, the route selected should use as much natural cover and concealment as possible, if there is no substantial increase in construction effort. Natural cover includes fence lines, hedge rows, and tree lines. The natural state of the pipeline route should be left as undisturbed as possible. Grading and leveling the pipeline route is undesirable from a concealment standpoint but can greatly increase the rate of construction of a aluminum pipeline system. The trade off between camouflage and rate of construction must be weighed.

b. *Procedure for Route Selection.* The pipeline engineer (normally the company commander), assisted by the combat heavy engineer battalion Operations and Training Officer (US Army) (S3), uses the pipeline design criteria to start laying out the route location. Time permitting, location of the route proceeds as follows: aerial photographic studies, field reconnaissance, and route survey and route profile plotting. (Profiles should not be made from maps except in critical situations).

(1) Map and Aerial Photograph Studies. Studying maps may eliminate obviously unsuitable routes. A plastic relief map of the area, if obtainable, will assist in preliminary planning, Topographic maps of large scale, with contour intervals of 20 feet or less, give best results. Aerial photographic strip maps provide a check on roads, streams, and other terrain features that may not show up on maps. In choosing a tentative pipeline route by map study, the engineer takes into account--

- Accessibility of the route for stringing and placing equipment.
- Natural and man-made obstacles that will require additional construction effort and material.
- Suitable pump-station and construction-staging-area locations.

- Suitable petroleum-terminal locations.
- Accessibility for patrol and maintenance.
- Elevation and hydraulic grade line.
- Stream banks. Avoid these, especially if the stream habitually floods lowlands.
- Heavily populated areas. Avoid these areas because of the potential fire hazard that the pipeline presents.

(2) Field Reconnaissance. Routes tentatively selected by map study should be thoroughly inspected in the field.

(3) Air Reconnaissance. Air reconnaissance of all tentative routes frequently eliminates all but two or three possible routes. The helicopter's altimeter will give a rough approximation of the elevation along the route, Also, air reconnaissance can help evaluate the adequacy of natural cover along the proposed route.

(4) Ground Reconnaissance. Reconnaissance by foot and motor vehicle is used to confirm the decision as to which route is most suitable. A stadia survey of the selected route should be made, if possible. Ground distances are determined by chaining or by stadia measurement when the survey is run. Using a surveying altimeter helps determine fairly accurate elevation approximations along the route. Each altimeter traverse should be run in loops, ending the same day during hours of practically uniform temperature and stable air pressure. Speedometer mileage and pace counting will assist in approximating distance measurements.

c. Map Layout and Profile of Pipeline Route. Once the pipeline route is selected, it is laid out on a map. The combat heavy engineer battalion conducts a ground survey to plot a profile of the route. The scale of the profile should be as follows: vertical, 1 inch equals 200 feet; horizontal, 1 inch equals 2 miles. This profile is used to locate pumping stations, pressure-reducing stations, and other pipeline installations.

Chapter Four. Design

4-1. Characteristics of Petroleum Fuels. The fundamental characteristics of fluids must be considered when designing petroleum pipeline systems. However, only the physical properties as they affect the storage of military fuels in terminals and their flow through pipelines are to be considered. These characteristics are weight density, specific gravity, American Petroleum Institute (API) gravity, viscosity, temperature, and pressure.

a. *Weight Density.* Density is a measure of the concentration of matter, weight is a measure of the force of gravity. Weight density is the weight per unit of volume. Added weight makes fluid movement more difficult. The densities of fluids are at the freezing point of water and under one atmosphere of pressure (the pressure at the earth's surface). The density of water is 62.4 pounds per cubic feet.

b. *Specific Gravity (SG).* Specific gravity is the ratio of the weight of a volume of liquid to the weight of an equal volume of water. For example, a cubic foot of diesel fuel weighing 53.04 pounds has a specific gravity of 0.85 (53.03 divided by 62.4).

c. API Gravity. The API gravity scale, used by the petroleum industry, is based on reciprocals of specific gravities and, therefore, produces whole numbers having a greater numerical spread. The API scale is in degrees API and has a range of O to 100 degrees. Water is referenced as standard and is assigned an arbitrary gravity of 10 degrees API. This gives a spread of 90 degrees API between the heaviest and lightest petroleum products. API gravity is inversely proportional to specific gravity: the lower the specific gravity, the higher the API gravity. Thus, petroleum products that have the lightest weight have the highest API gravities. The standard temperature for expressing API gravities is 60°F. So, gravities taken at other temperatures must be corrected to 60°F.

(1) Conversion Formulas. Use the following formulas to convert between API gravity (at 60°F) and specific gravity:

$$degrees\ API = \frac{141.5}{SG} - 131.5$$

$$SG = 141.5\ (degrees\ API + 131.5)$$

(2) Design Fuel. This is the fuel type for which a pipeline system is designed. Military pipelines most likely will transport diesel and jet fuels and kerosene. Federal specifications list the properties of these fuels. Table 4-1 (page 4-2) shows the gravity range of the most common military fuels. The spread between the heaviest and lightest fuels is 34 degrees API. Because of this spread, specific gravity is an important factor in the design of military pipelines. The anticipated quantities of different fuel types to be pumped must be considered. The heaviest fuel is the design fuel, which makes up 25 percent or more of the total requirement. Under normal conditions, a pipeline designed for diesel fuel can handle other fuels effectively. Further discussion is based on diesel fuel that has an average specific gravity of 0.8967 (26.3 degrees API). This provides a basis for comparison of capacity and performance when heavier or lighter products are to be moved.

Table 4-1. Gravities of military fuels (60°F)

Fuel	Degrees API Gravity			
	From	To	Average	Specific Gravity
Diesel	24.3	27.4	26.3	0.8927
Gasoline	55.1	61.4	58.4	0.7451
JP4	45.0	57.0	51.0	0.7753
JP5	36.0	48.0	42.0	0.8165
JP6	46.0	50.0	48.7	0.7852
JP8	37.0	51.0	44.0	0.8075
Kerosene	39.0	46.0	42.0	0.8156

d. *Viscosity.* Viscosity is a measure of the flow of a liquid. It is the internal force (resistance) or opposition to flow. The greater the internal force, the more viscous the liquid. Since a viscous liquid resists efforts to move it, absolute viscosity is defined as a measure of the force required to produce flow. In the electric system, the unit of absolute viscosity is the poise, which is equal to one dyne-second per square centimeter (100 centipoises). Viscosity and specific gravity are related; the relationship is expressed as kinematic viscosity, which is the ratio of absolute viscosity, in poises, to specific gravity of the liquid. The unit of kinematic viscosity is the stoke given in units of square centimeters per second (100 centistokes). Viscosity in stokes multiplied by specific gravity equals viscosity in poises. The viscosities of military fuels are found in Appendix C or in federal specifications.

e. *Temperature.* The above characteristics are affected by temperature. Volume and API gravity increase with temperature while density, specific gravity, and viscosity vary inversely. Because of these effects of temperature, all measurements are corrected to 60°F. This is the standard temperature for both design and operation of military pipeline systems. Correction factors are found in Appendix C.

f. *Pressure.* In pipeline design, the elevation of fuels from one level to another, their movement from place to place, or both are governed by the principles of hydraulics. In the military pipeline system, the areas of interest are the--

- Behavior of liquids at rest (hydrostatic pressure and equilibrium), as in a storage tank or slack line.
- Forces exerted on liquids by objects in motion (hydrodynamics), as in pumping equipment.

In actual application, all forces that produce pipeline flow and those opposing it can be described or measured in terms of pressure or head. Coupled military pipelines are low-pressure systems that operate at a normal working pressures of no more than 740 psi. Low-pressure pipelines require that pumping stations be spaced closer than high-pressure lines to get the same throughput. Lighter pipe, used in low-pressure pipelines, is easier to construct, and it avoids the mechanical failures inherent at higher pressures. However, welded military pipelines can operate at higher pressures. Head (or pressure) in a pipeline is either static or dynamic. However, you must consider atmospheric pressure and vapor pressure.

(1) Static Head. Static head is a measure of pressure in liquids at rest. It is also a measure of potential energy (energy of position). Static head is the vertical height from a given point in a column or body of still liquid to its surface (usually expressed in feet). To calculate the pressure in water, use the following formulas, which are also found in Appendix A:

$$P = \frac{(h)\,(SG)}{2.31} \quad or \quad P = (0.433)\,(h)\,(SG)$$

and

$$h = \frac{(2.31)\,P}{SG} \quad or \quad h = \frac{P}{0.433\,(SG)}$$

where--

P = *pressure, in psi.*
h = *head, in feet.*
SG = *specific gravity.*

Because of their lower specific gravities, static pressures of petroleum products are proportionally less.

(2) Dynamic Head. Dynamic head is a measure of pressure, or kinetic energy, of liquids in motion. Figure 4-1 (page 4-4) shows the relationship between static head and dynamic head. The distance from the liquid level in the tank to ground level is the static head. As liquid starts to flow down the pipe, it loses static head but gains velocity and dynamic head. Dynamic head is greatest at the ground level where the flow changes direction and the streams begin to rise in the air. After that, dynamic pressure or head decreases until all velocity is lost. During this action, the stream recovers some of its initial static head. The difference between the initial static head and the final static head or dynamic head is the head loss, which represents friction losses due to pipe and air. In summary, dynamic head is equal to the static head required to accelerate the flowing velocity of the stream.

(3) Atmospheric Pressure. Atmospheric pressure is comparable to static pressure in liquids because it is caused by the weight of air above the earth's surface. Atmospheric pressure is about 14.7 psi at sea level. It decreases somewhat at higher altitudes. The maximum suction lift is about 33.96 feet of water (14.7 x 2.31 =33.96). Because elevation affects atmospheric pressure, pump engines are affected at elevations above 3,000 feet, and design loads on pumps are decreased about 4 percent per each 1,000 feet above 3,000 feet.

(4) Vapor Pressure. All liquids, particularly light fuels, have a tendency to vaporize. This tendency (volatility) increases with temperature and decreases with pressure. The vapor pressure of a system is a function of the temperature and pressure of the system. However, the effect of total pressure on the vapor pressure is small, so the vapor pressure of a system is usually regarded as a function of temperature only. Vapor pressure begins to exceed atmospheric pressure at the boiling point of a liquid. The boiling point varies; at high altitudes, liquids boil at lower temperatures than at sea level. Vapor pressure reduces the effect of atmospheric pressure acting on a liquid and affects pumping operations involving suction lift.

Figure 4-2 (page 4-5) shows the theoretical suction-lift values for military fuels. The height of the bar graphs shows the maximum net suction lift for water and petroleum products after vapor pressure has been deducted from atmospheric pressure. For example, Figure 4-2 shows that diesel at normal atmospheric pressure (14.7 psi) theoretically can be lifted, by suction, over 38 feet at 50°

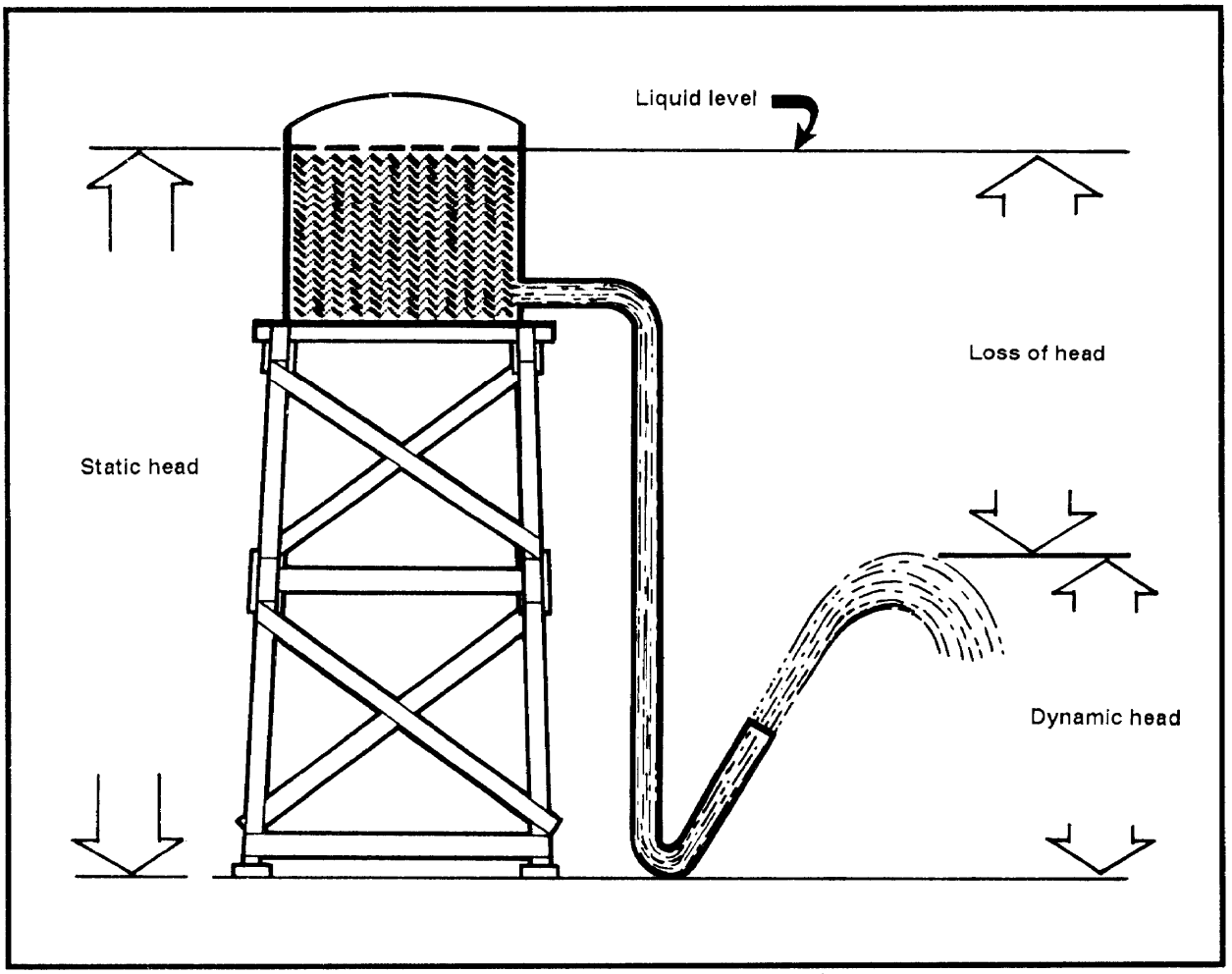


Figure 4-1. Static head versus dynamic head

F, about 35 feet at 100°F, and about 33 feet at 200°F. If atmospheric pressure is reduced, the net maximum suction lift also will be reduced. To show this, reduce the atmospheric pressure 3 pounds below normal. Lay a straight edge on the chart with one end on the point representing 3 psi on the atmospheric scale and keep the edge parallel to the baseline. The reading should show that 3 psi atmosphere equals 9 feet suction lift for Type A motor gasoline (MOGAS). Comparatively, Type A MOGAS cannot be lifted this distance by suction at 135°F, and the net lift at 100°F and 50°F is reduced to 7 feet and 21 feet respectively (16-9 and 30-9). Therefore, normal suction pressure of 20 psi should be increased to 30 psi for operating temperatures over 100°F. (Special conditions from those just described apply to station 1 on a pipeline.)

4-2. Pipeline and Pumping-Station Data.

a. *Pipelines.*

(1) Capacity. Pipeline capacity (throughput) is the quantity of fuel pumped per unit of time. Generally, it is expressed in barrels per hour (BPH) or GPM. One barrel is equivalent to 42 US gallons. Table 4-2 (page 4-6) shows the normal and emergency capacities of military pipelines. Normal capacities are used for pipeline designing.

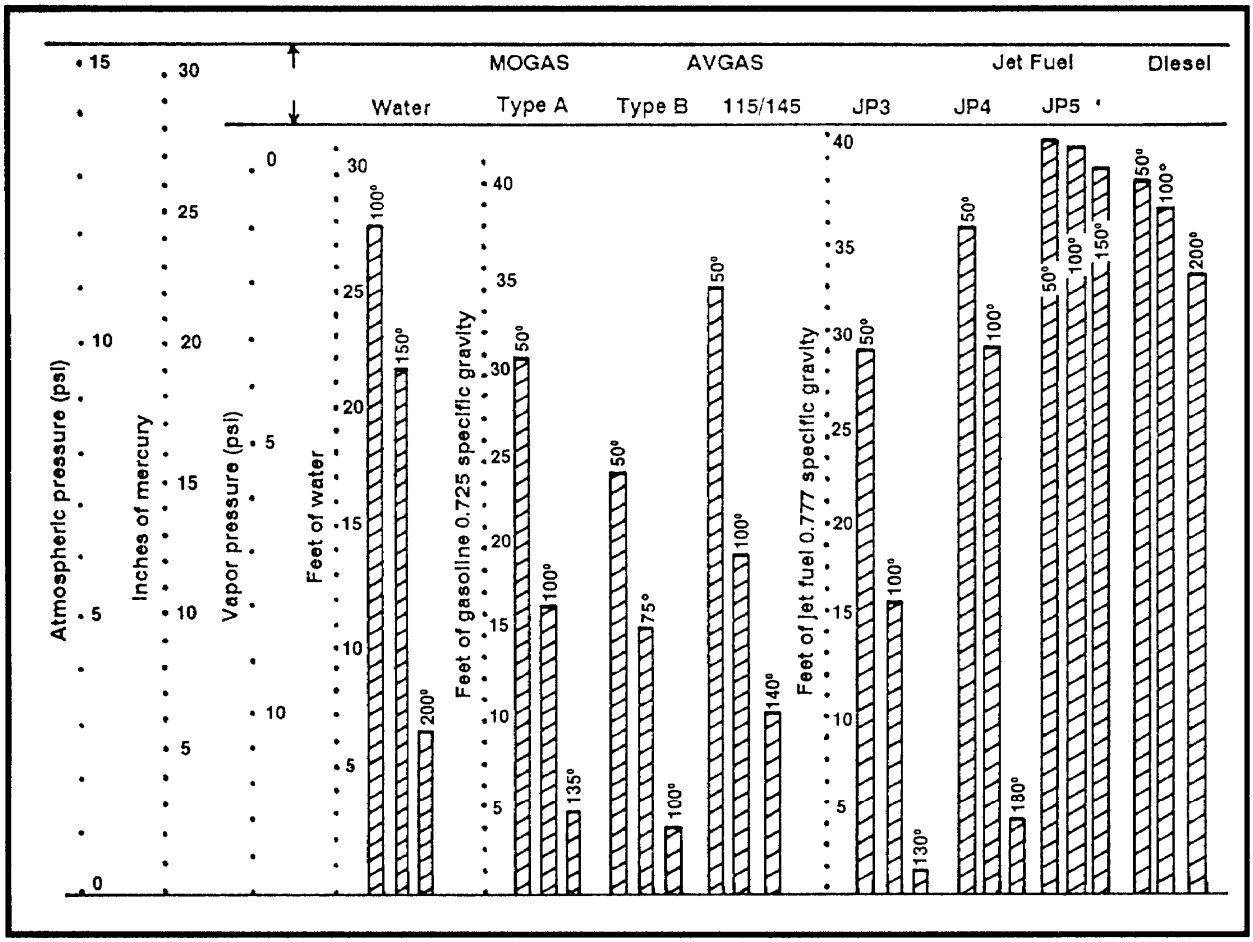


Figure 4-2. Theoretical suction-lift values for military fuels

(2) Flow Velocity. With a specified pipe size and a given throughput requirement, the flow velocity is constant for all practical design purposes, using average conditions of climate and topography. See Table 4-2 (page 4-6) for average velocities of flow, in feet per second.

(3) Pipeline Pumping Pressures. Normal working pressures are used in pipeline design. Emergency capacities are dictated by the tactical situation. Table 4-2 (page 4-6) lists safe working pressures for lightweight pipe or tubing. These safe working pressures are based on the yield point of the pipe material and provide a designed minimum safety factor of 3.0. Table 4-3 (page 4-8) lists pipeline pumping pressures for normal and emergency design capacities.

(4) Flow Resistance. A liquid's resistance to flow in a pipeline results from the following:

- Friction of the pipe walls.
- Viscosity of the liquid.
- Special factors such as entrance to the pipe, sudden changes in flow direction or cross-sectional area, flow through equipment like traps and meters, and corrosion or deposits in the line. Resistance usually is expressed in terms of the pressure required to overcome resistance, in psi or in feet of head of the liquid pumped.

Table 4-2. Design capacity of standard military, lightweight steel and aluminum pipe

OD (in)	ID (in)	Barrels (per hour)	Velocity (ft/sec)	Average station spacing (miles)	Maximum safe working pressure (psi)
Normal Design Capacity					
4.500	4.350	355	5.5	7.9	600
6.625	6.415	785	5.4	16.6	600
6.625*	6.249	857	6.3	15.0	740
8.625	8.415	1,355	5.6	16.6	500
12.750	12.481	7,150	12.5	1.1	400
Emergency Design Capacity					
4.500	4.350	393	6.1	7.9	600
6.625	6.415	1,000	6.8	16.6	600
6.625*	6.249	1,143	8.3	9.0	740
8.625	8.415	1,730	6.7	16.6	500
12.750	12.481	11,400	20.0	0.5	400

* Aluminum pipe, based on fuel of 0.85 specific gravity; all others based on 0.725 specific gravity. Station spacing on level terrain.

b. *Head Capacities of Pumping Units.*

(1) Normal Head Capacity. The normal head capacity (see Table 4-3, page 4-8) of a pumping unit is the total head against which it will pump at the most efficient operating point. The head capacity for a particular pump varies according to its design efficiency. Head capacity is a function of speed (operation), in RPM versus its rate of discharge (GPM). In other words, the design speed of the pump unit (RPM) must be considered together with the required head and desired throughput (GPM) to establish maximum efficiency in pipeline design.

(2) Emergency Head Capacity. Emergency head capacity (see Table 4-3, page 4-8) of a pumping unit is the total head against which it will pump to provide maximum pipeline capacity. Maximum head capacity is for emergency operation only and is never used as the basis for design. Pumping stations should operate at maximum head capacity only during critical tactical emergencies.

NOTE: For convenience, all operating graphs for military pump units are in Appendix C.

c. *Use of Pumping Unit Operating Graphs.* Pumping unit operation graphs (performance curves) graphically display the interrelationship between pressure (in feet of head and/or psi), pump speed, and throughput. From these graphs, you can estimate the pumping unit's operating speeds, the volume of fuel throughput, or the operating head as long as you know two of the three factors.

For example, to determine the throughput of 0.85 SG fuel moved by a 6-inch, 3-stage, 800-GPM mainline pump (IPDS), operating at 1,800 RPM with a dynamic head loss of 500 psi or 1,360 feet of head, proceed as follows:

(a) Find the pumping unit operating graph for the specific pump in Appendix C.

(b) Determine the dynamic head loss, in psi and feet, for the fuel type and enter the chart from the left side.

(c) Draw a horizontal line from the dynamic head loss to the established pump speed.

(d) Draw a vertical line at the point where the horizontal line intersects the pump-speed curve. Exit the chart at the bottom to determine throughput, which is 500 GPM.

d. *Friction Loss.* The two sources of friction within a pipeline system are friction resulting from fluid flowing through the pipe and friction created by fuel passing by obstructions, such as valves, fittings, and pipelines of smaller diameters. The total friction loss in a section of pipeline, usually expressed in feet of head per unit of pipe length, is the total of the two friction losses. The total friction loss represents the total energy, or head, expended in moving the fuel through a pipeline. In design, this information serves as a parameter on which to base the distances between pumping stations on level terrain. You can calculate friction loss by using the Darcy-Weisbach equation shown in Appendix A or the graphs in Appendix C.

(1) In Pipes. Pipe friction loss arises from the internal friction of the particles of the fluid itself (viscosity) and the resistance to flow at the pipe-wall surfaces. The viscosity of a fluid indicates the friction expected from a given flow.

(2) From Fittings. Friction loss through fittings results from the same surface friction as losses in straight pipe. Such losses for all fittings except plug valves are determined by converting each type fitting into its equivalent pipe length and then determining the friction loss. To do this, find the intersection of a straight line between the valve type and the inside pipe diameter scales in the equivalent pipe length of pipe fittings chart in Appendix C. Determine the friction loss for the equivalent pipe length as discussed above. Table 4-4 (page 4-8) shows the approximate pressure loss through lubricated plug valves.

e. *Computing Friction Loss.*

Problem and Solution #1

Calculate the friction head loss per mile to move gasoline in an aluminum pipeline with an ID of 6.249 inches. The pipeline design requires one check valve and one gate valve every mile and *U*-loop expansion devices every 1,000 feet of pipeline. The design flow rate is 550 GPM. Use the following computations to solve the problem:

Step 1. Pipe Length.

Running length = *5,280.00 feet*
Expansion devices = *200.64 feet (19 ft x 2 x 5.28 (number/mile))*
Total = *5,480.64 feet*

Step 2. Pipe Length Equivalents for Pipe Fittings.

Gate valve, 1 each at 4.5 feet equivalent	= *4.50 feet*
90-degree elbow, 4 x 5.28 x 6.7 feet equivalent	= *141.50 feet*
Check valve, 1 each at 50.0 feet equivalent	= *50.00 feet*
Total	= *196.00 feet*

Table 4-3. Operating characteristics of standard pipeline pumping stations[1]

Size of Line Nominal (in)	Pump Units per Station		Normal Design Capacity							Emergency Capacity						
	Number	Type	Number of pumps operating	Net available head (ft)	Net available pressure (psi)	Barrels per hour	Barrels per day (24-hour operation)	Engine speed (rpm)	Hydraulic horsepower	Number of pumps operating	Net available head (ft)	Net available pressure (psi)	Barrels per hour	Barrels per day (24-hour operation)	Engine speed (rpm)	Hydraulic horsepower
4	2	A	2	1,072	336	355	8,520	1,800	48.7	2	1,321	614	393	9,432	2,000	66.4
6	4	A	3	1,362	427	785	18,840	1,800	136.8	4	2,233	700	1,000	24,000	2,000	285.7
6*	2	C	1	1,800	565	857	20,570	2,000	197.7	1	1,800	565	1,143	27,429	2,100	263.3
8	4	B	3	973	305	1,355	35,520	1,850	168.7	4	1,522	477	1,730	41,520	2,100	336.8
8	2	B	2	313	98	2,860	68,640	1,850	114.4	2	354	111	3,570	85,680	2,100	161.7
12	4	B	4	201	63	7,150	171,600	1,850	183.8	4	217	68	11,400	273,600	2,100	316.4

[1]Based on fuel of 0.725 specific gravity and normal operating conditions
A - 4-inch, 4-stage
B - 6-inch, 2-stage
C - 6-inch, 3-stage
*6-inch aluminum pipe based on 0.85 specific gravity fuel

Table 4-4. Approximate pressure loss through lubricated plug valve (equivalent feet of pipe)

Nominal Size (in)	125-pound cast iron and 150-pound nonferrous metal			250-pound cast iron		150-pound steel			300-pound steel		
	Regular	Short pattern wedge gate	Venturi	Regular	Venturi	Regular	Short pattern	Venturi	Regular	Short pattern	Venturi
6	12	44	36	12	36	9.6	14.4	36		43	
8	18	54	54	18	54	12.0	48.0	54	9.6	54	54
10	24	60	60	24	60		54.0	60		66	60
12	30	72	78		78		72.0	84			77

Problem and Solution #1 (continued)

Step 3. Pipe Length and Fittings.

Length of aluminum pipeline (from (1))	*= 5,480.64 feet*
Length of fittings (from (2))	*= 196.00 feet*
Total	*= 5,676.64 feet*

Step 4. Friction Loss in Pipe and Fittings. Find the head loss due to friction chart in Figure C-9 (page C-8). Enter the chart at the bottom with the design flow rate of 550 GPM. Draw a vertical line up until it intersects the slanting line marked 6.249 (the ID of the aluminum pipe). From this intersection, trace a horizontal line to the friction loss scale on the left side of the chart. On this scale, the friction loss in feet of head per mile should be 90. Use the following equation to compute the friction loss equivalent length of 5,676.6 feet:

$$actual\ head\ loss = \frac{head\ loss}{unit\ distance}\ x\ actual\ distance$$

$$actual\ head\ loss = \frac{90\ feet}{5{,}280\ feet}\ x\ 5{,}676.64\ feet$$

$$actual\ head\ loss = 96.76\ feet\ of\ head$$

f. *Reducing Friction Loss.* Reducing friction loss may be required when design errors or other factors, such as terrain or time, have led to the placement of pumping stations too far apart to maintain the design flow rate. The three remedial methods for reducing friction loss are using larger pipe, using double-looped lines, and reducing the flow rate.

(1) Using Larger Pipe. If a problem is anticipated and material is available, using larger pipe to reduce friction loss will save time and work; you will not have to lay the line twice. The following problem and solution shows how to use the larger-pipe method for reducing friction loss:

Problem and Solution #2

The friction loss in a 1,786-foot section of 6 5/8-inch steel tubing must be reduced to a maximum allowable head of 18 feet under maximum emergency flow conditions. Maximum emergency rate of flow is 928 BPH. You must determine the maximum length of 8 5/8-inch tubing required to reduce the head loss to 18 feet. Solving this problem is based on the principle that total head or pressure loss in a section of pipeline, which consists of two sizes of pipe in series, is equal to the sum of the friction losses for each size and length of pipe. The following equation explains the principle:

$$F = L_1 (f_1) + L_2 (f_2)$$

where--

Problem and Solution # 2 (continued)

F = *total friction loss, in feet of head.*
L = *pipe length, in feet.*
f = *friction loss, in feet of head per 1,000 feet for the specific type of pipe.*

The total friction loss must be no greater than the maximum allowable 18 feet of head. L_1 is the length of the 8 5/8-inch tubing, in units of 1,000 feet. L_2 is the length of the 6 5/8-inch tubing, in 1,000-foot units, and equals 1.786 minus L_1. Convert the maximum flow of 928 BPH to 650 GPM and use 8.415 inches (as ID of 8 5/8-inch tubing) to determine that the friction loss per mile is 29 feet. Convert this to friction loss (f_1) per 1,000 feet by dividing 29 feet per mile by 5.28 (thousand feet per mile) which equals 5.5 feet of head loss per 1,000 feet. For a flow of 650 GPM and an ID of 6.415, f_2 is equal to 21.8 feet of head loss per 1,000 feet. Using the base formula and the above figures, solve for L_1 as follows:

$$18 = L_1 (5.5) + (1.786 - L_1)\, 21.8$$
$$18 = (5.5)\, L_1 = (38.93 - 21.8)\, L_1$$
$$18 - 38.93 = (5.5)\, L_1 - (21.8)\, L_1$$
$$(21.8)\, L_1 - (5.5)\, L_1 = 38.93 - 18$$
$$(16.3)\, L_1 = 20.93$$
$$L_1 = \frac{20.93}{16.3}$$

L_1 = *1.28 thousand-foot sections or 1,280 feet of 8 5/8-inch steel tubing.*

(2) Using Double Lines. If larger pipe is not available, you can reduce friction loss by laying additional pipe parallel to the first and connecting the two. The following problem and solution demonstrates this method:

Problem and Solution #3

The conditions are the same as for the larger-pipe method; however, you are to determine the length of double line necessary to reduce the head loss to 18 feet. Use the same base formula in solving this problem. Before starting, you must determine how to compute the friction loss (f_1) for the length (L_1) of double line. The principle is that the flow rate in each half of a double line is considered to be half that of a single line of the same length.

As before, the total friction loss must be no greater than the maximum allowable 18 feet of head. L_1 is the length of double 6 5/8-inch line required. L_2 is the length of one 6 5/8-inch line in 1,000-foot units and equals 1.786 - L_1. The friction loss for the double line is half the emergency rate (928 BPH) or 464 BPH. Convert 464 BPH to 325 GPM and use 6.415 inches as the ID to determine that f_1 equals 31 feet of head loss per mile or 5.87 (31/5.28) feet of head loss per 1,000 feet of

Problem and Solution #3 (continued)

double line. For a flow of 650 GPM and an ID of 6.415, f_2 equals 21.8 feet of head loss for each 1,000 feet of single line of 6 5/8-inch steel tubing. Using the base formula and the above figures, solve for L_1 as follows:

$18 = L_1 (5.87) + (1.786 - L_1) 21.8$
$18 - 38.9 = (-21.8) L_1 + (5.87) L_1$
$(21.8) L_1 - (5.87) L_1 = 38.9 - 18$
$(15.9) L_1 = 20.9$
$L_1 = \frac{20.9}{15.9}$
L_1 = *1.3 thousand-foot sections or 1,300 feet of double-line 6 5/8-inch steel tubing.*

g. *Spacing of Pumping Stations.* An important element in the design of a military pipeline system is pumping-station spacing. The spacing is determined by the hydraulic designs and the pump-unit capabilities. The hydraulic design considers the friction head loss in the pipe and changes in elevation of the pipeline when it operates at normal design capacity. When a pipeline runs uphill, the stations are closer together; when it runs downhill, the stations are farther apart. The distance between pumping stations is based on the friction head loss over distance, which is increased or decreased based on changes in terrain. The key factor in pumping-station placement is that all pumping stations are in balance hydraulically and are operating at the same rate (even work-load distribution). Table 4-2 (page 4-6) shows the average spacing of pumping stations on level terrain for various sizes of pipelines, based on maximum safe working pressures. The design factors that determine pumping-station spacing are the--

- Topographic features of the pipeline route.
- Type and properties of the design fuel (viscosity).
- Required suction pressures, available head capacities, and other operating characteristics of the pumping unit.
- Friction head losses based on flow rate for the selected size of pipe and fittings.

h. *Modular Design.* Modular design is a simplified graphical method of locating pumping stations (except station 1) and pressure-reducing stations. This method is essentially the solution of hydraulic calculations by means of graphs. The graphs required area profile of the pipeline route and the hydraulic gradient triangle.

The hydraulic gradient triangle is a right triangle that is constructed on the same scale as the profile. The triangle's altitude (vertical distance) represents the available feet of head pressure at the discharge of the pumping station. The base (horizontal distance) represents the distance that the fluid can be moved on level terrain, which is based on the available head of the pumping unit, the friction head loss in the pipeline, and the design flow rate.

The hypotenuse of the triangle, the result of a vector diagram, is the hydraulic gradient. This gradient represents the rate of head loss due to friction for a specific pipe size carrying a specific fluid at a specific rate of flow. If the pipe size, type of fluid, or flow rate is changed, a new triangle must be constructed. Generally, when this triangle is applied to the pipeline profile at the same scale, with the right angle corner on the location of one pumping station and with the base parallel to the base of the profile, the point at which the hypotenuse (hydraulic gradient) or its extension intersects the profile is the maximum distance to the next pumping station.

The modular-design method is accurate enough for most tactical situations. A more exact method of determining friction head loss and the energy relationship for liquid flowing through a pipe between two points can be calculated by the Darcy-Weisbach and Bernoulli equations (Appendix A). A complete hydraulic analysis should be prepared to verify the modular design as time permits.

i. *Construction of the Hydraulic Gradient Triangle.* You can construct this triangle from transparent plastic sheets, cardboard, or paper thick enough so that after trimming, each edge can be used as a straight edge. The following problem and solution shows how to construct a typical hydraulic gradient:

Problem and Solution #4

You are to construct a hydraulic gradient triangle for a pipeline with normal design capacity of 550 GPM for diesel fuel at 60°F. You will be using a 6-inch, 3-stage, 800-GPM, mainline pumping unit and 6.625-inch (6.249-inch ID) aluminum pipe. The normal design head capacity of each pump unit is 1,800 feet. Two pumps make up a standard aluminum system pumping station. The pipeline profile has the following scale: vertical, 1 inch equals 200 feet; horizontal, 1 inch equals 2 miles. Construct the triangle with a 90-degree angle at A as follows:

Step 1. Draw the altitude (AB) of the triangle to the same scale as the vertical scale of the pipeline profile in Figure 4-3. The height represents the available fluid head in feet at design rate of flow at the pumping-station discharge. The height is graduated in suitable units, usually 10 feet. See Table 4-3 (page 4-8) for the design capacity for this pump. The available head capacity is 1,800 feet. This is the altitude of the hydraulic gradient triangle. The scale is 1 inch equals 200 feet, so the altitude is 9 inches.

Step 2. Draw the base (AC) of the triangle to the same scale as the horizontal scale of the pipeline profile shown in Figure 4-3. The length represents the distance, in miles, that the available discharge head of the pumping station can move the fluid at normal design rate of flow on level terrain. To determine the length, divide the available head of the pumping station by the friction loss per mile for the specific tubing at the specified design flow rate.

Problem and Solution #4 (continued)

Step 3. Use Figure C-9 (page C-8) to find the friction head loss at 550 GPM in an aluminum pipeline (6.625-inch ID). The friction head loss is 97 feet per mile. However, the friction head-loss factor is for gasoline at 60°F and must be corrected for diesel by using the correction factors in Appendix C. To correct the friction head loss for diesel, multiply 97 by 1.09 to get 105.7 feet of head loss. Divide the available head by the head loss per mile to get a distance of 17 miles (1,800/105.7). This is the base of the hydraulic gradient triangle. The scale is 1 inch equals 2 miles, so the base is 8.5 inches.

Step 4. The hypotenuse (BC) of the triangle is the straight line that connects points B and C (see Figure 4-3). This slope represents the loss of head per unit length of pipeline and establishes the gradient for determining station spacing.

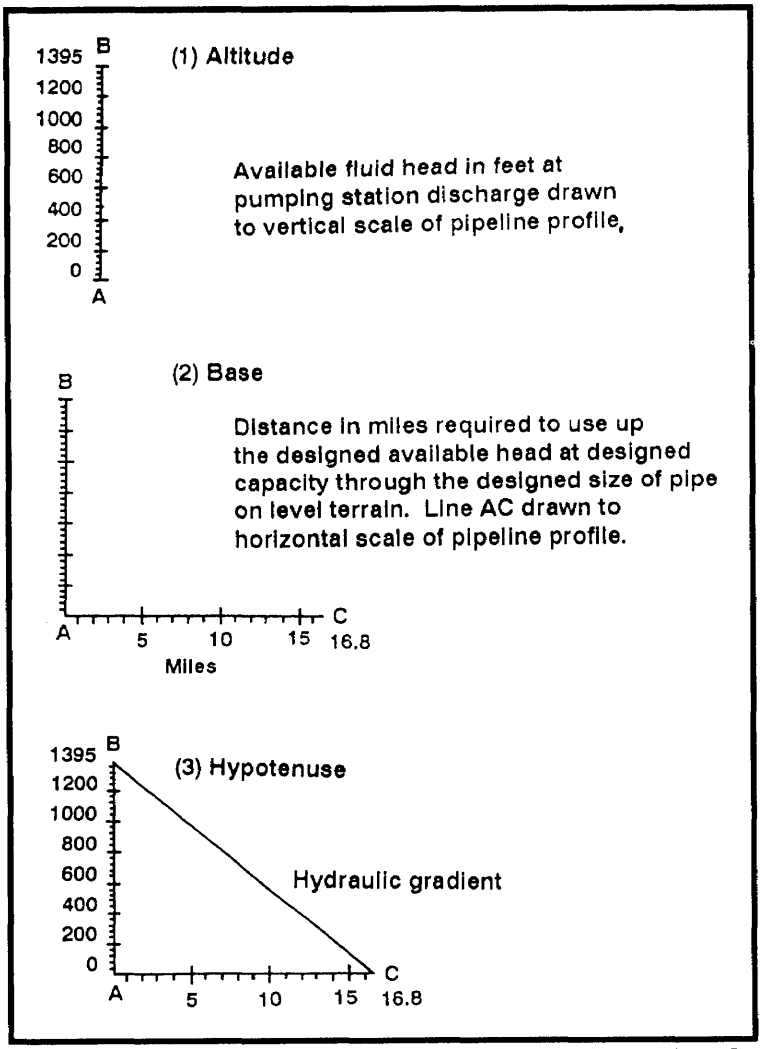


Figure 4-3. Constructing a hydraulic gradient triangle

4-3. Location of Pumping Stations. The following paragraphs describe the factors considered in locating mainline pumping stations and flood or suction stations for military pipelines. Mainline pumping stations, with the exception of station 1, are placed by the modular method described above. Locations of other pumping stations require special analysis for each station site.

a. *Pumping Station 1.* This station (base terminal) receives fuel from a petroleum-terminal tank farm or host- nation supply. Station 1 is located as far from the tank farm as possible for safety and convenience of operations. Because of its critical position, the station and the connecting line to the tank farm require careful planning and design to ensure that sufficient suction pressure is provided to the first mainline pumping station under design-flow conditions. The suction pressure at station 1 should be at least 20 psi. If the required suction pressure for station 1 cannot be created by gravity, a flood or suction pump is required.

(1) Gravity System. In determining whether gravity will furnish sufficient suction pressure for station 1, proceed as follows:

(a) Select a tentative site for the station, the elevation of which is below the outlet of the lowest tank in the tank farm.

(b) Determine the available head from gravity by computing the difference in elevations of the tank outlet and the pump-suction manifold entrance at the proposed pumping station.

(c) Calculate the total friction loss in feet of head for the pipe and fittings used to connect the tank to the pumping station for the design flow conditions. Make sure that friction loss is corrected for design fuel.

(d) Determine the net head available at the station by subtracting the friction head loss at the design rate of flow from the head available from gravity.

(e) Convert the net available head to suction pressure in psi by using the conversion formula in Appendix A. When the suction pressure is greater or equal to 20 psi, the mainline station 1 can be fed by gravity flow from the tank farm.

(2) Alternative Methods. If gravity does not furnish enough suction pressure at any suitable site for station 1, determine if using the larger-pipe method or the double-line method will reduce friction loss enough to eliminate the need for a flood or suction pumping station. If analyses show that gravity feed with either method will not provide enough suction pressure, then install a flood or suction pumping station.

Problem and Solution #5

The outlet of the lowest tank in the petroleum tank farm is 150 feet higher than the pump suction manifold entrance of proposed station 1. The suction pressure required at station 1 is 20 psi. Connections between the tank and the pumping station consist of 680 feet of 6.249-inch ID aluminum pipe, two gate valves, five 45-degree elbows, two 90-degree elbows, and two through-run *T*s. The design flow rate of the pipeline is 650 GPM of 0.85 specific gravity diesel fuel at 60°F

Step 1. Total equivalent length of fittings.

Gate valve, 2 each at 4.50 feet	= *9.00 feet*
45-degree elbow, 5 each at 4.50 feet	= *22.50 feet*
90-degree elbow, 2 each at 6.70 feet	= *13.40 feet*
Through-run T, 2 each at 6.70 feet	= *13.40 feet*
Total	= *58.30 feet*

Step 2. Total length of pipe and fittings.

Pipe length, 6.249 ID	= *680.00 feet*
Equivalent length of fitting	= *58.30 feet*
Total	= *738.30 feet*

Problem and Solution #5 (continued)

Step 3. Total friction loss (Appendix C).

Friction loss in 6.249 ID pipe	*= 130.00 feet per mile*
Corrected for 60°F diesel (130 x 1.09)	*= 141.70 feet per mile*
Friction loss per 1,000 feet $\frac{141.7}{5.28}$	*= 26.84 feet*
Total friction loss (0.73830 x 26.84)	*= 19.82 feet of head*

Step 4. Net head available.

Gain in head from elevation	*= 150.00 feet*
Total friction loss	*= 19.82 feet*
Net head gain	*= 127.77 feet*

Step 5. Suction pressure available (Appendix A).

$$\frac{(130.18)\ (0.85)}{2.31} = 47.90\ psi$$

This particular site and pipe layout provides sufficient suction pressure for station 1. Required suction pressure is 20 psi and available pressure from gravity is 47.90 psi. To prevent vapor pockets in a gravity line, the grade from the tanks to the pumping station need not be uniform but should be free of excessive humps, pockets, and sharp bends.

(3) Flood Pumps. When gravity will not supply sufficient suction pressure for station 1, install a flood or suction pumping station as close to the tank-farm manifold as safety conditions permit. See Chapter 2 for operating characteristics on pump units.

b. *Pumping Station 2.* The location of pumping station 2 by use of the hydraulic gradient triangle depends on the positive suction pressure at station 1. Station 2 will maintain the minimum suction pressure that is to be passed along to each succeeding station on the pipeline. This pressure is 20 psi at normal elevations and temperatures.

When suction pressure at station 1 is 20 psi, station 2 is easily located. Place the hydraulic gradient triangle on the pipeline profile with point A (the right angle) at station 1. The base (AC) of the triangle is positioned parallel to the horizontal baseline of the profile in the direction of flow in the pipeline. The point at which the hypotenuse of hydraulic gradient line (BC) intersects the profile is the proper location for station 2. The pressure at this point will be 20 psi, the same as the suction pressure at station 1. The triangle has measured the pumping distance for only the pressure added by the pumps at station 1, and the suction pressure does not have any bearing. In other words, station 1 started with a suction pressure of 20 psi.

c. *Stations on Equal Elevations.* If the pipeline profile does not intersect the hypotenuse of the hydraulic gradient triangle, the distance between two successive pumping stations on equal elevation is determined simply by the pressure drop due to pipeline friction. Hills and valleys along the route cancel each other out, and there is no loss of pressure due to changes in elevation.

For example, suppose that station 3 is at the same elevation as station 2. You would locate station 3 by placing point A of the hydraulic gradient triangle on the point fixed as station 2 on the profile. The base extends in the direction of flow and parallel to the baseline of the profile. If the two stations are actually on equal elevation, station 3 will be located where Point C of the triangle lies on the pipeline profile (see Figure 4-4).

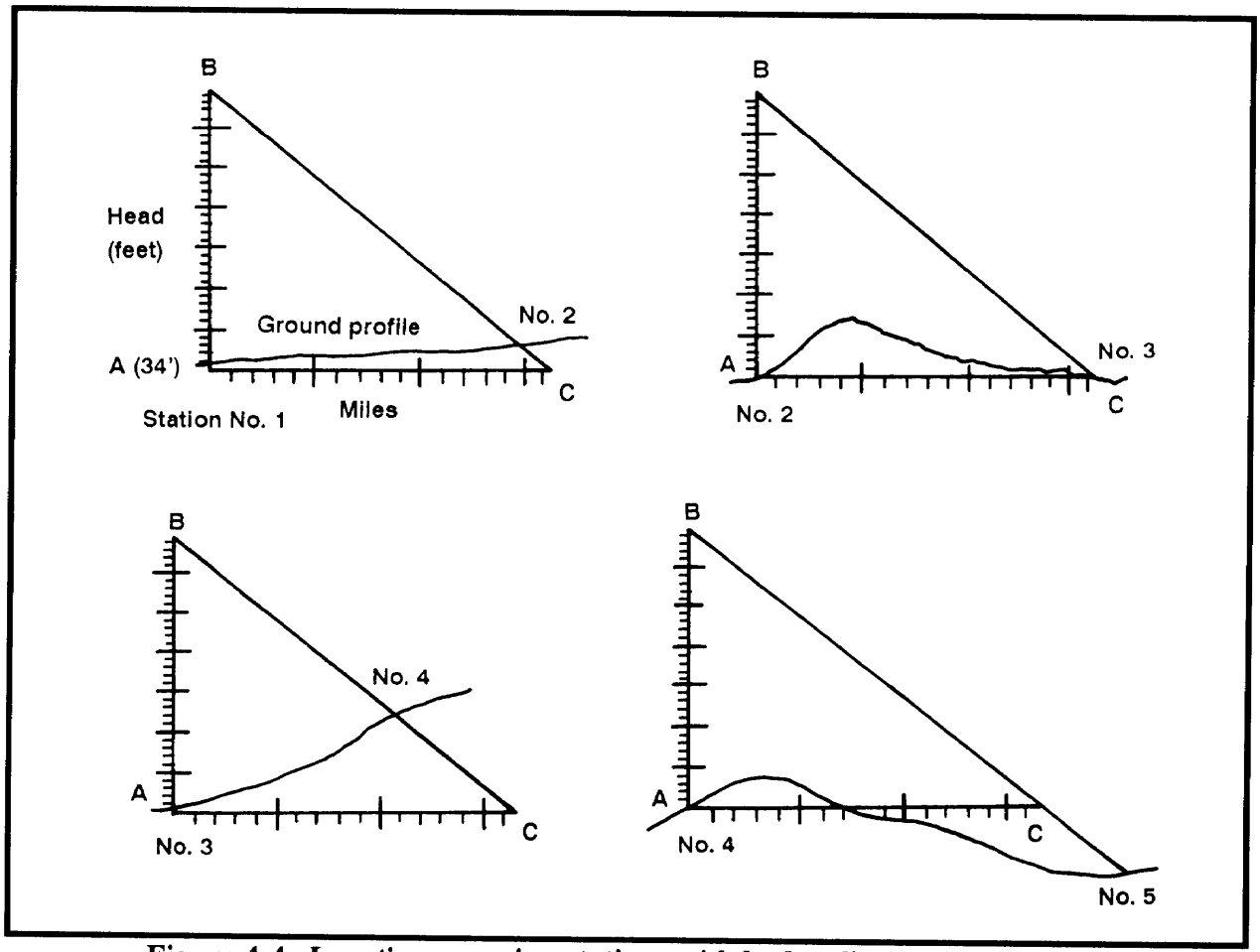


Figure 4-4. Locating pumping stations with hydraulic gradient triangle

d. *Stations on an Upgrade.* A downstream pumping station that is at a higher elevation than the preceding station is said to be on an upgrade. The total pressure loss between the two stations equals the sum of the separate losses due to friction and the difference in elevation. Logically, the downstream upgrade station will be closer to the preceding station than a downstream station at an equal elevation.

Suppose, because of the terrain, that station 4 is at a higher elevation than station 3. To locate station 4, place point A of the hydraulic gradient triangle on the point representing station 3 on the profile, with the base extending in the direction of flow and parallel to the baseline of the profile. The first point at which the hypotenuse or hydraulic gradient of the triangle intersects the profile is the appropriate location for station 4 (Figure 4-4).

e. Stations on a Downgrade. A downstream pumping station that is at a lower elevation than the preceding station is said to be on a downgrade. The pressure loss between stations will amount to the difference between the friction loss in the pipe. The pressure gain (static head) is due to the lower elevation of the downstream pumping station. A downstream station at a lower elevation than the preceding station will be farther from that station than it would be if both stations were at an equal elevation.

Suppose that pumping station 5 (downstream) is at a lower elevation than station 4 (upstream). To locate station 5, place point A of the hydraulic gradient triangle on the point that represents station 4 on the pipeline profile, with the base extending in the direction of flow and parallel to the baseline of the profile. Extend the hypotenuse (BC) until it crosses the profile of the pipeline. The point where BC intersects the profile is the proper location for station 5 (Figure 4-4).

f. *Pressure-Reducing Stations.* When pumping is interrupted and the pipeline is shut down, fluid in the line exerts static pressure between points of unequal elevation. Since there is no counteracting friction loss from fuel flow to use up or offset the static head, the total static pressure caused by the elevation difference is exerted against the pipe and the valve, which stops the flow. During normal flow, the safe working pressure of the pipeline may not be exceeded. During shutdown, the total static pressure applied may be well above the safe working pressure, especially at low sections in the line. To prevent this, place pressure-reducing stations on downgrades at all points where static pressure may become excessive.

To determine where to install a pressure reducing station in the line, construct a feet-of-head scale, similar to the line AB of the hydraulic gradient triangle in Figure 4-3 (page 4-13), equal to the safe working pressure of the pipe being used. Be sure to use the same vertical scale as the pipeline profile. With the scale, measure downward from the highest elevation on the profile; at its base, project a horizontal line in the direction of the downgrade. The point where this horizontal line intersects the profile is the proper location of the pressure-reducing station (see Figure 4-5, page 4-18). For example, the safe working pressure for 6.247 ID aluminum pipe (Table 4-2, page 4-6) is 740 psi, which equals 2,011 feet of head for 0.85 specific gravity fuel by using the conversion factor in Appendix C.

The following methods are used to regulate static pressure in long downhill sections of military pipeline. Conditions, availability of materials and equipment, or other considerations will dictate which method you should use to protect the line when static pressure exceeds the capability of the pipeline tubing.

(1) Pressure-Reducing Valves. These valves will reduce upstream pressure about 25 to 800 psi and require no special tools to install. If these valves are available, using them is the best and easiest method of controlling excessive pressure.

(2) Heavier-Weight Pipe. When the higher safe working pressures of standard pipe can withstand static pressure, replace the lighter pipes on long downhill sections with heavier pipes to control the increased pressure exerted during shutdown. For example, the safe working pressure for 6-inch (0.219-inch wall thickness), standard-weight pipe is 1,000 psi. For 0.85 specific gravity fuel, the equivalent feet-of-head is 2,506 feet. In this example, replace the lightweight pipe with standard-weight pipe below the elevation in which the pipe strength is exceeded by static pressure.

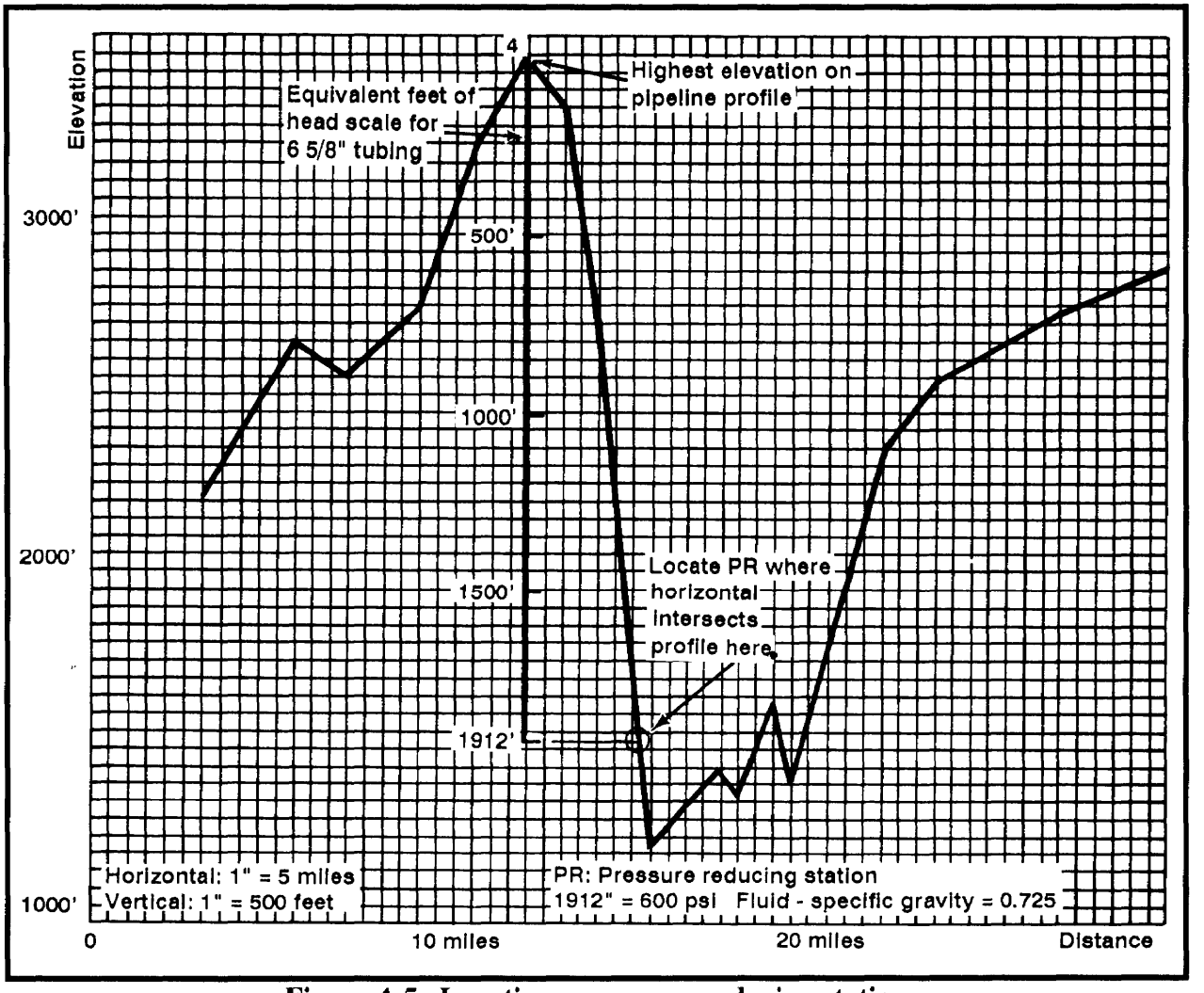


Figure 4-5. Locating a pressure-reducing station

g. *Field Location of Pumping Stations.* After the hydraulic locations of the pumping stations have been plotted on the profile of the pipeline (Figure 4-4, page 4-16), a site reconnaissance is made and the locations are plotted on topographic maps. The exact sites are located by measuring distances from easily identified landmarks or terrain features.

The pumping-station locations selected using the hydraulic-gradient-triangle method may not be suitable for many reasons. The locations may be inaccessible, difficult to camouflage, or too small; they may have poor vapor drainage or involve other unsuitable terrain conditions. If this occurs, the pumping station should be shifted upstream or downstream to a better site on the pipeline. Remember that a change in location also will change the suction and discharge pressures of the pumping station.

(1) Relocation Upstream. If a station must be relocated upstream, the available discharge head is equal to the normal discharge head plus the head from friction and elevation gained between the new location and the original location. Pressure conditions at the design rate of flow at the new pumping-station location must be reviewed to determine if discharge pressure of the preceding pump

will exceed the maximum working pressure of the pipeline. If a station is relocated upstream, the next upstream station is relocated also so as to restore the proper 20-psi suction pressure.

(2) Relocation Downstream. Pumping stations may be shifted a short distance downstream on the pipeline to take advantage of good sites. However, the suction pressure at the relocated station cannot fall below 20 psi. The proper suction pressure must be restored at the succeeding pumping station. Relocation upstream is the best choice because the only effect on operations is an increase in suction pressure over the normal 20 psi. Relocation downstream without reduction of throughput can only be done by sacrificing part of the suction pressure. This should not be done unless minimum suction pressure can be maintained.

h. *Poor Locations for Pumping Stations.* A pumping station in a poor location either cannot pump at the required flow rate or it can pump at the required rate but with less than normal pressure. If a station fails to maintain flow at normal pressures, you can loop the line, or you can use larger pipe for a suitable distance on the downstream side of the pumping station to reduce friction loss by an amount that will permit it to pump at the design rate.

If a station does not have to pump under full pressure to pump at the required rate, it may be operated with fewer than the required number of pumping units. Or, when the station has to use only 50 percent or less of normal pressure (or lower RPM throttled back), the line may be looped around the next upstream station, which can then be eliminated from the line.

4-4. Treatment of Unusually Steep Grades. With unusually steep grades, it is possible that the safe working pressure of the pipe may be exceeded by dynamic head under normal design flow conditions.

Problem and Solution #6

The design flow is 550 GPM of 0.85 specific gravity fuel. The equipment used is 6.249 ID aluminum pipe and a 1,800-foot head-capacity pump. To determine whether the safe working pressure has been exceeded, compare the true hydraulic gradient triangle with the pipeline profile.

Step 1. Draw the true hydraulic gradient (Figure 4-6, Step l, page 4-22) by placing the hydraulic gradient triangle on the profile of the last located pumping station. Point A should be on the pumping-station location; the base should extend in the flow direction and parallel to the baseline of the profile to point C. Add the suction pressure that is passed on from station to station by extending the available head scale from point B to B_1, a distance equal to that suction head pressure or 54 feet (0.85 specific gravity fuel at 20 psi). From this point B_1, draw a line on the profile parallel to the hypotenuse of the hydraulic gradient triangle. This line, B_1 to C_1, is the true hydraulic gradient at design flow.

Step 2. On a stiff piece of cardboard or clear plastic make a feet-of-head scale corresponding to the safe working pressure of the pipeline. Label this scale D to E (see Figure 4-6, Step 1, page 4-22). The equivalent feet-of-head for 6.249-ID aluminum pipe at 0.85 specific gravity with a safe working pressure of 740 psi is

Problem and Solution #6

2,011 feet. Move this scale along the hypotenuse of the true gradient triangle with the point E on the true hydraulic gradient and the scale perpendicular to the baseline of the profile. Mark the point on the pipeline profile where the bottom edge of the scale first passes through the pipeline profile P_1. Continue moving the scale along the true hydraulic gradient hypotenuse, and mark the profile at the point at which the bottom edge of the scale again passes through the profile P_2.

Step 3. The section of the pipeline between points P_1 and P_2 will build up dynamic pressure exceeding the safe working limits of the aluminum pipe used under design-flow conditions. For this critical section, redesign the line. You can redesign by replacing the aluminum coupled pipe in the high-pressure segment of line with standard welded pipe. The following effects will result:

- The safe working pressure in the standard pipe (0.219-inch wall thickness) is higher.
- The smaller ID (6.187 inches) of the standard pipe creates a greater head loss per mile and consequently a steeper slope in the hydraulic gradient in that portion of the line in which it is used.

Step 4. Make a new hydraulic gradient triangle for the standard pipe using the same scale as the pipeline profile. The altitude is 1,800 feet or the available head capacity of the pump unit. The base is figured by dividing the available head capacity of the pumping unit by the line loss per mile based on design flow. In this example, the pump capacity is 1,800 feet of head, and the design flow capacity is 550 GPM. The friction head loss for standard pipe (0.219-inch wall thickness) is 90 feet per mile. Calculate the base by dividing 1,800 feet of head by 90 feet of head loss per mile. The result is 20 miles. Use the same scale to construct a new hydraulic gradient triangle. Place the new hydraulic gradient triangle, based on standard pipe (Figure 4-6, Step 2, page 4-22), with point B_2 on the true gradient at the point exactly above P_1 with the base extending in the direction of flow and parallel to the baseline of the profile. With the triangle in this position, draw the new hydraulic gradient on the profile.

Step 5. Conduct a test to determine if the safe working pressure of the standard pipe is exceeded at any point. Construct a feet-of-head scale for standard pipe as in Step 2 above. See Table 4-2 (page 4-6) for dimensions and safe working pressures for standard pipe supplied in pipeline assemblies. In Figure 4-6, Step 2, (page 4-22) the scale F to G is the safe-working-pressure scale for 6-inch standard pipe (0.219-inch wall thickness). For this pipe, the maximum safe working pressure is 1,500 psi, which is equivalent to 3,759 feet-of-head of 0.85 specific-gravity fuel.

Problem and Solution #6 (continued)

Step 6. Check the vertical distances between the new hydraulic gradient and the pipeline profile as in Step 2 above. If the bottom edge of the feet-of-head scale does not pass above the pipeline profile at any point, the safe working pressure of the standard pipe is not exceeded. Using the feet-to-head scale for the aluminum pipe (D to E), prepared according to Step 2 above, locate the point on the profile where the pressure drops below the safe working pressure of the aluminum pipe tubing by moving the scale along the new hydraulic gradient based on standard pipe. The point (P_3) at which the bottom edge of the scale first passes below the profile is the transition point where aluminum pipe may be used again in the pipeline.

Step 7. Locate the next pumping station (Figure 4-6, Step 3, page 4-22) using the original hydraulic gradient triangle. Position the feet-of-head scale directly above the transition point between standard pipe and aluminum pipe (P_3). Add the suction head pressure required at each pumping station (20 psi or 54 feet) to the feet-of-head scale, which is the same as B_1 in Step 1 above. Position point B_1 of the triangle on the new hydraulic gradient. This procedure restores the standard pumping-station suction pressure. Draw a line parallel to the original true hydraulic gradient until it intersects the pipeline profile. The point where this line intersects the pipeline profile is the proper location for the next pumping station.

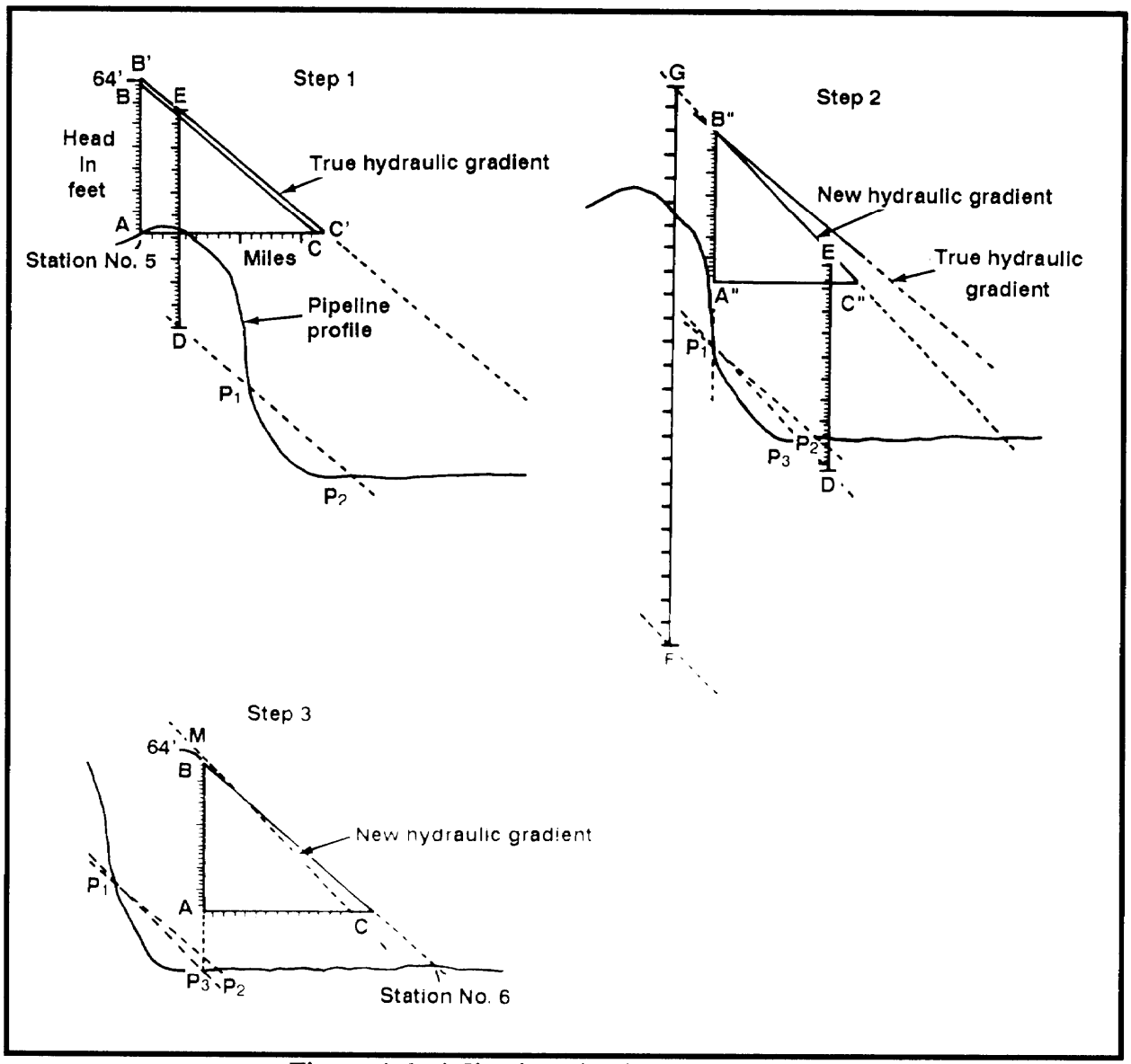


Figure 4-6. Adjusting pipeline to steep slopes

Chapter Five. Construction

5-1. Introduction. Military pipeline construction is a very labor-and equipment-intensive mission. When logistics planners determine that a military pipeline is required, equipment and labor support must be allocated in sufficient quantities to meet the required rate of construction. Additional material-handling equipment and transportation assets, not within the engineer organizations, must be allocated to move, load, and unload pipeline materials from the port of entry to the construction staging areas.

A platoon can construct about 1 1/2 miles of coupled pipeline per day, based on terrain and obstacles they must cross. On flat terrain with limited obstacles, a highly trained crew can lay up to 2 miles per day. In mountainous terrain with numerous obstacles, the same crew may be able to construct only 1/2 mile per day. The main factors to consider in estimating rate of construction are terrain, obstacles, weather, tactical situation, and location of the construction staging areas and construction access road to the pipeline route.

a. *Task Organization for Construction.* The organization of a unit indicated by its table of organization is a generalized concept. Many minor changes must be made to effectively use the available skills for a specific job or project. A pipeline construction support company is designed to provide technical expertise to a battalion-size, engineer construction unit for pipeline construction. The general construction unit can be made up of either troop or civilian labor. The design rate of construction will determine the task organization between the specialized pipeline construction company and the general construction unit. The general command structures of both units should be retained, as much as possible, to ensure maximum command and control. For example, a general engineer platoon could be assigned a pipeline construction squad for technical expertise.

b. *Construction Standards.* Military pipeline-construction standards must be established and met from start to finish. Pipeline failure has serious consequences. Fuel loss or delay of its supply can disrupt combat operations. Avoidable repair or reconstruction wastes time, troops, and materials that could have been used elsewhere.

Taking time to correct past mistakes may mean that the pipeline does not keep pace with advancing combat operations. Troops may have to use trucked-in fuel. They could eventually outstrip the pipeline or run out of fuel. Repairing a leaking or broken pipeline can be extremely hazardous and life-threatening. Detailed fire-prevention precautions are necessary, requiring a disproportionate amount of military effort. Miles of pipeline may have to be drained into tank trucks or into hastily excavated sumps. The environmental impact of such activities must be planned for. Main supply routes adjacent to the pipeline may have to be blocked to facilitate the repair. The following are the minimum standards for military pipeline construction:

(1) Pipes. Keep pipes clean and free from debris at the time of construction. Small quantities of loose material in each pipe length can accumulate in sufficient volume to clog sand traps or strainers located at pumping stations. Before coupling or welding pipe lengths together, inspect

them for cleanliness inside and out. Run a swab or wire brush through each length to clean out any debris just before connecting it to the line. Aluminum pipes are equipped with end caps that should remain in place until the pipes are coupled. Discard any badly corroded pipes.

(2) Pipeline Components. Each connection in the pipeline should stand up to the design pressure without leaking so that the agreed-on, allowable, product loss rate can be met. With coupled connections, the coupling will leak if the pipe ends, gaskets, or the couplings themselves are defective, damaged, or dirty.

(a) Pipe ends. Inspect pipe ends for dents, out-of-roundness, paint, scale, rust, or other irregularities. The pipe end (land end) must be smooth and within 1/32-inch round for a tight joint. (In the field, you cannot hammer or sway back into shape any ends that are dented or bent out-of-round.) Remove all loose paint and scale from the nipple ends; file off any burrs or rough edges. Make sure you keep nipple lands, gaskets, and coupling halves clean throughout the coupling operation.

(b) Coupling gaskets. Coupling gaskets must fit smoothly inside the coupling halves. Discard any gasket that shows signs of age (excessively hard, cracked, or cut).

(c) Couplings. Inspect couplings for any cracks or gouges due to rough handling. A damaged coupling will not withstand the pressure that a coupled pipeline is designed for.

(d) Hose line. Inspect all hose lines for dry rot. Do not use a hose line that has dry rot.

5-2. Coupled Pipeline Systems.

a. *Coupling Procedures for 6-Inch Aluminum Pipe and 4- and 6-Inch Steel Pipe.* For military use, coupled pipelines are preferred over welded pipelines because they can be constructed quicker. To couple pipe sections together, groove the pipe ends to facilitate a coupling and gasket assembly. Grooved pipe is available in standard-weight and lightweight steel and lightweight aluminum. (The lightweight pipes are also referred to as tubing.) See Chapter 2 for more information on pipeline components. Use the following procedures when coupling a pipeline using 6-inch aluminum pipe or 4-and 6-inch steel pipe:

(1) Stake Pipeline Route. Marking crews, working ahead of construction crews by at least one day, stake out the final location of the pipeline and its installations using wooden stakes. If clearing and leveling are required, they must mark the route in advance. These markers should be visible, one from the other, at maximum intervals of about 500 feet. The crew leader should be experienced in pipeline construction. Good layout can greatly reduce the construction effort. Markers can be color-coded to furnish detailed information to construction crews. Table 5-1 lists suggested stake colors for various types of installations.

Table 5-1. Suggested stake colors

Installation	Stake Color	Instructions
Route	Plain	Stakes numbered in sequence
Pumping station	Blue	Station number and distance from #1 marked on stake
Gate valve	Green	
Check valve	Yellow	
Pressure-reducing station	Red	

(2) Clear and Level Pipeline Route.

(a) Clearing. Clear the pipeline route just enough to get the line laid efficiently and permit patrolling. Keep clearing to a minimum to save time and maximize natural vegetation for camouflage. Clear enough vegetation so it does not restrict operations. Use a 4-ton bolster trailer pulled by a 5-ton truck to get pipe to the ground efficiently. The cleared route should be just wide enough (about 25 feet) for construction vehicles to gain access and for the pipe to be unloaded. Two-way traffic will require additional space.

Vegetation type and construction method determine the extent of clearing necessary. Areas containing dense growth usually require more clearing than forests containing large trees. In dense areas, the pipe sections cannot be aligned, and the construction crew has insufficient working space unless a lane is cleared through the areas. Forests that have large trees usually have very little undergrowth. Laying the pipeline between the trees should be possible. The construction crew will have to string the tubing sections manually. However, the total effort and time required may be less than that required to cut a trace through heavy stands of large timber.

When working in heavy forests, the crew should use farm access roads or old logging trails when off-loading pipe to reduce the distance that pipe must be carried manually. In an open field with high vegetation, mark the line adequately with signs to prevent damage by cross-country traffic.

(b) Leveling. Leveling the terrain is critical when constructing coupled aluminum pipelines but not that critical for coupled steel pipelines. The reason is that the maximum allowable coupling deflection for the aluminum pipeline system is 2 degrees; whereas, the coupling deflection in the steel system is much greater and need not be considered. Level terrain reduces the requirement for extensive sandbagging to align the aluminum pipeline system. Minor obstacles should be leveled or pushed aside with a bulldozer.

(3) Determine Valve Locations. Gate, check, and vent valves are the most common valves installed in a pipeline system. The number and location of each must be predetermined, so sufficient quantities can be pre-positioned at construction staging areas that will supply that section of the pipeline.

(a) Gate valves. These valves are located at intervals in the pipeline for repair purposes. The number and location are based on the tactical situation. Pipeline lengths that are susceptible to damage, such as by bridges, should be isolated at each end by a gate valve. When enemy activity is anticipated to be low in the theater rear area, gate valves are installed about one every mile. Gate valves should be accessible from the road.

(b) Check valves. These valves are placed in the line at the bottom of steep upgrades to prevent backflow in case of shutdowns. When enemy activity is anticipated to be low in the theater's rear area, check valves are installed about every three miles.

(c) Vent valves. These valves provide an outlet for air in the pipeline. They are installed about every mile at the top of the highest terrain.

(4) Construct Pipeline Obstacle Crossings. Try to avoid major obstacles, such as steep cliffs, deep ravines, large boulders, and swampy areas, when selecting the pipeline route. Use existing

road culverts whenever possible. Crossing obstacles can significantly slow down the construction rate. If an obstacle crossing facility must be constructed, it should be completed before the coupling crew completes the line to that point. This will eliminate the need for the construction crew to return to the site later to connect the line. If the line is constructed after the obstacle-crossing device is built, a custom-cut piece of pipe (pup joint) will be required. Each pup joint must be cut and grooved on each end, which takes a trained operator about 60 minutes. Pup joints should be made at a central location, like the construction staging area, to reduce the setup time required.

Studying maps and aerial photos when planning the pipeline route can help reduce the number of crossing sites. It may become necessary to traverse pipeline obstacles such as roadways, rivers, streams, and drainage ditches. Aluminum pipelines must be supported at least every 19 feet. The maximum unsupported span of steel coupled pipelines should not exceed 40 feet. The following obstacle-crossing kits are available through AFCS:

(a) Nestable culvert material. The best way to cross a road with pipeline is through an existing culvert. The 5-mile pipeline set has nestable culvert material. It should be installed to the same standards as a culvert installed for drainage. Steel sleeves can be used instead of nestable culvert. They do not have to be assembled, but they do require additional transportation and material handling equipment.

(b) Gap support structure with pipeline roller assembly. This structure and assembly (Figure 5-1) is used for crossing small streams and gullies. It consists of 4-inch diameter steel tubing and angled steel and roller assemblies. The rollers are installed so the pipeline can move during expansion and contraction. The structure must be fabricated on-site and is placed at intervals equal to the length of a stick of pipe, with the coupling positioned directly between the structures. Expedient gap-crossing structures (Figure 5-2, page 5-6) may be required if kits are not available.

(c) Suspension-bridge kits. These kits (Figure 5-3, page 5-7) are available in 100-,200-, and 400-foot spans. Detailed assembly instructions come in the packing list for each kit. If suspension kits are not available, expedient-crossing structures can be constructed.

(5) Prepare Construction Staging Areas. The construction staging area receives, accounts for, and issues construction materials. The location and operation of staging areas are key to maximizing the rate of pipeline construction. Pipeline components are moved from a central location to the construction staging area by stake and platform (S&P) trucks or similar means. Pipeline components are moved from construction staging areas by bolster trailers. Using a 5-ton cargo truck with a 4-ton bolster trailer is the best way to transport pipe sections from the construction staging area to the pipeline trace. (Using a 5-ton bridge truck is second choice.) A bolster trailer can holdup to 50 pieces or sticks of 19-foot, 6-inch diameter aluminum pipe when extensions are installed on standard stanchion assemblies. Be careful when loading and unloading bolster trailers holding more than 35 sticks of 6-inch pipe because of the height that you must lift the pipe when loading and unloading.

As the intermediate transfer point of pipeline components, the construction staging area reduces the turnaround time required for the movement of pipeline components to the trace. A constant supply of pipeline materials to the stringing and coupling crews is the key to maximum laying rates. Construction staging areas should be located about every 10 miles along the pipeline route. Each

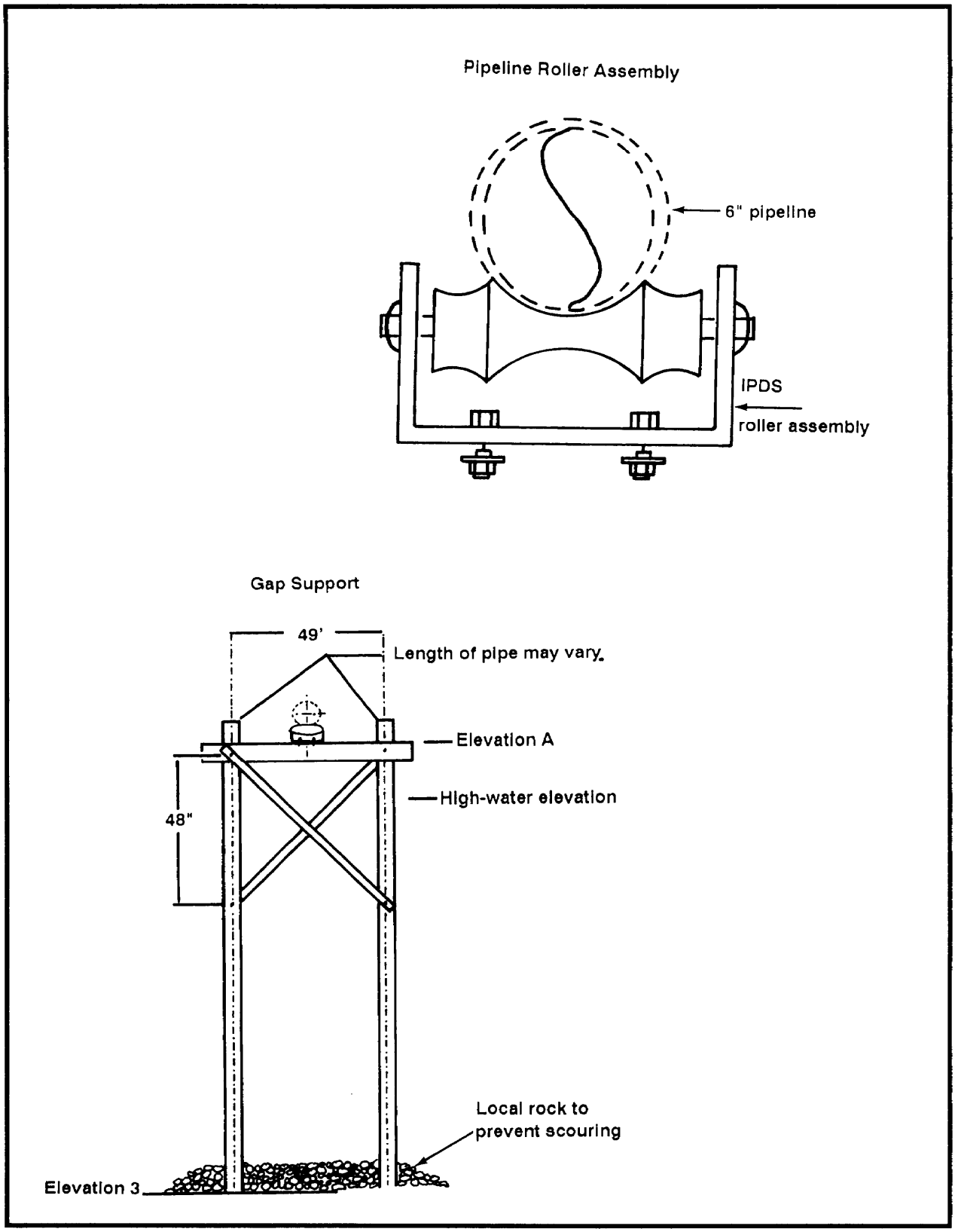


Figure 5-1. Critical gap-crossing structure

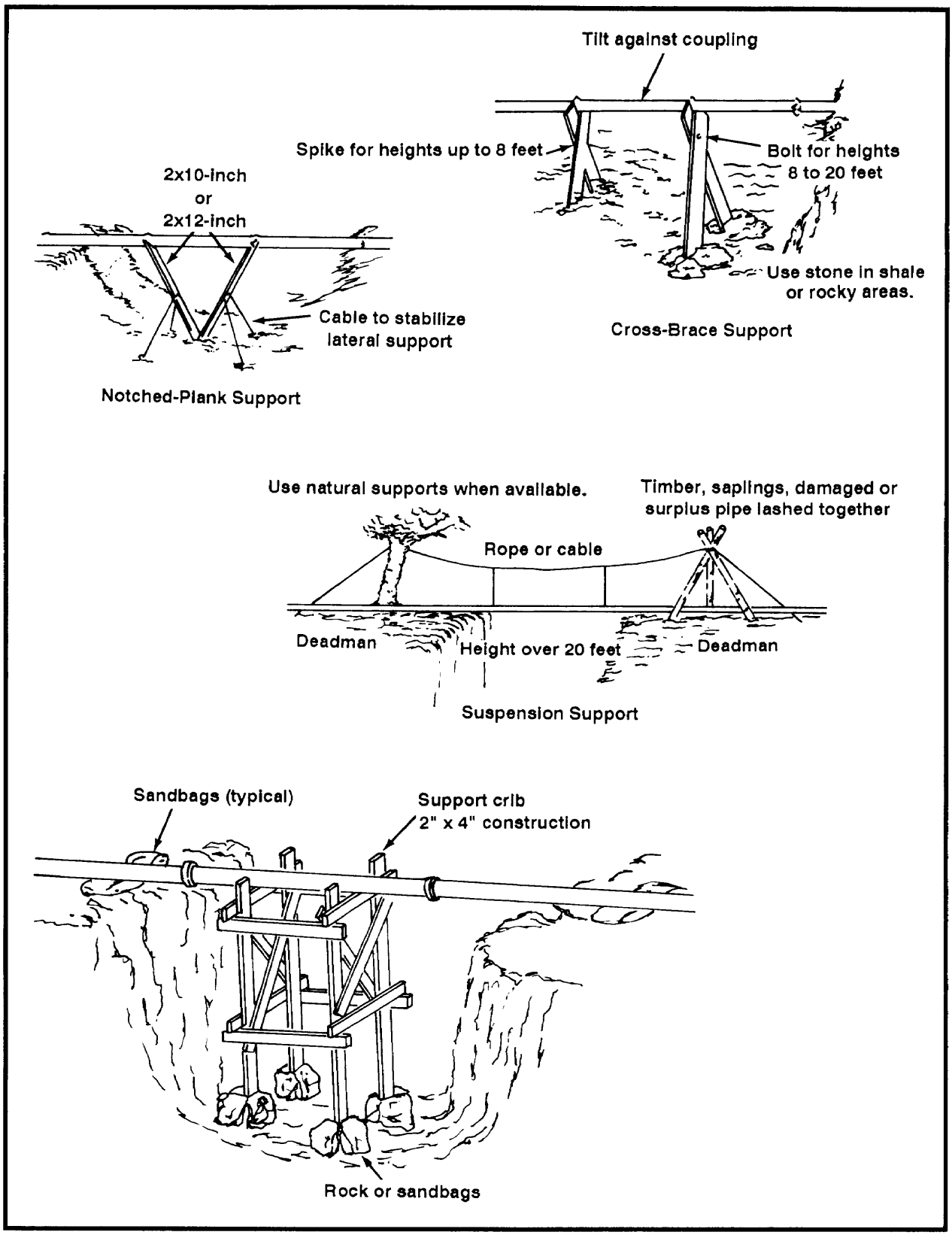


Figure 5-2. Expedient gap-crossing structures

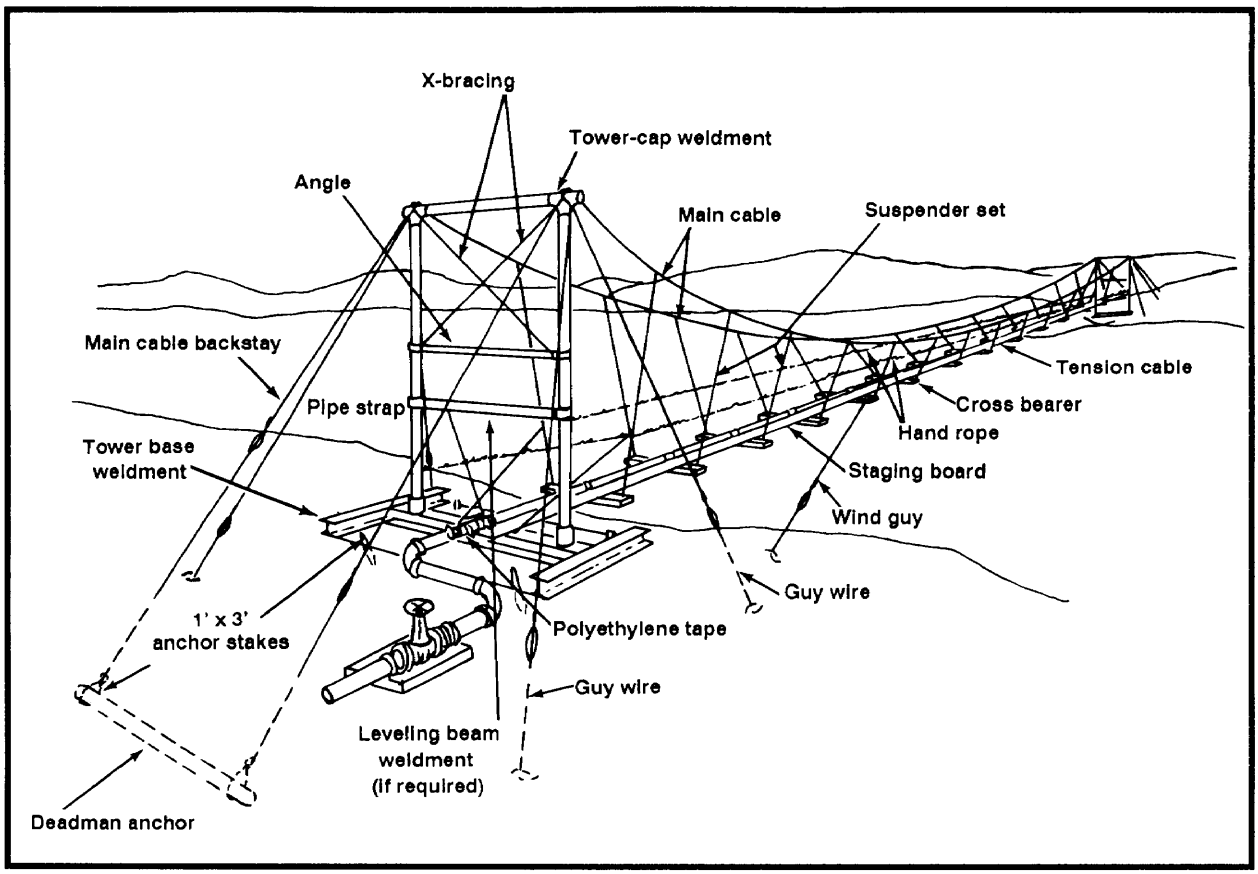


Figure 5-3. Suspension-bridge kit

area must be large enough (about 100 yards by 50 yards) to store pipeline components and allow for loading operations.

Loading crews should not accompany the transport vehicles to the construction staging area. All loading operations at the construction staging area should be accomplish by a dedicated crew who will remain at that area. The crew size will depend on factors such as the number of stringing crews that it is servicing and the type of terrain on which the pipe is being constructed. Normally 10 to 12 soldiers are required, including equipment operators.

You will need at least one 10,000-pound, rough-terrain forklift to operate the staging area. Based on the required construction rate, more than one staging area may be operational at the same time. The layout of components within the staging area is a key factor in determining expedient loading and unloading. The following guidelines apply:

- Keep vehicular traffic flow one way within the staging area.
- Do not handload any aluminum pipe or steel tubing sections larger than 6 inches and standard-gauge steel pipe larger than 6 inches.
- Load couplings and valves at the same time as pipe sections. (You may have to improvise regarding a container for couplings.)

(6) Assign Crews to Pipeline Construction Areas. Pipeline stringing and coupling crews are assigned sectors along the pipeline trace. The size of the sectors will depend on the number of pipeline construction crews available and the number and size of construction staging areas that can be operated effectively at the same time. For example, if you have two operating staging areas with 10 miles of components each and five available crews, each crew would have a 4-mile sector or 20 miles divided per five crews. After a crew is finished in its sector, it is assigned a new one.

(7) Place Pipes and Valves. Off-loading and placing pipe sections along the pipeline route end to end is known as *stringing.* Two soldiers can off-load 4- or 6-inch diameter steel or aluminum tubing sections. Manually stringing 6-inch (170-pound) pipe is hazardous work. Normally, eight men are required to properly string such pipe. If the tubing sections have to be carried farther than 25 feet, more men are needed.

The stringing crew is made up of three teams of two soldiers each who move pipe from the bolster trailer to the ground; one soldier places coupling materials, the other is a supervisor/ground guide. The crew down loads pipe as the truck moves slowly along the trace.

WARNING

Be very careful when stringing pipe at night. Soldiers could be injured by a moving truck.

As the crew unloads each section, they place it end to end in close alignment with the preceding section. A coupling and a gasket are placed close to each end-to-end junction. The crew off-loads an extra tubing section for every 50 to 75 sticks. This section will be a replacement for a damaged section or a filler for any gap that may develop. Laying the extra section saves time. These sections can be recovered later if they are not used.

The crew chief should be experienced in coupling operations so he can envision the final position of the pipeline. His experience will help prevent a situation such as laying pipeline on the wrong side of a tree.

When stringing aluminum pipeline, expansion loops must be laid out for at least every 1,000 feet of pipeline. There should be enough vehicles assigned so that the stringing crew always has a vehicle waiting to be unloaded. Rehandling pipe should be avoided as much as possible. However, some rehandling may be unavoidable when terrain conditions prevent vehicles from following the pipeline trace. If this occurs, the stringing crew may have to create roadside stockpiles as close as possible to the route and then reload the pipe on 1 l/4-ton trucks or carry it by hand to the trace. In very difficult terrain, helicopters, beasts of burden, or indigenous civilian labor may have to transport pipe to the trace.

The supervisor must carefully monitor the soldiers as they unload, string, and couple the pipe sections together so they do not--

- Damage the land surface on the nipples (the pipeline will leak).
- Shove tubing sections or grooved pipe off the rear of a vehicle.

- Hold onto the rear end and let the vehicle pull ahead until the forward end drops off the vehicle.
- Throw or drop sections over the side.
- Throw or allow sections to roll down embankments.
- Raise the front end of the truck or execute a *jackrabbit* start, which causes the load to slide off the rear.

Check valves and gate valves are the most commonly used valves along a pipeline. These cannot be manually down loaded safely. A 7 1/2-ton crane or a SEE is best for this task. Valves are normally positioned just before the pipe is coupled at that location.

(8) Couple the Pipeline. Coupling pipe sections together is the most critical task in pipeline construction. Coupling is a time-consuming and strenuous task. If done incorrectly, the pipeline will leak under pressure. Repairing a leaking pipeline is a time- and labor-intensive task and should be avoided. The most common cause of a leaking joint is a pinched gasket, which is normally the result of hasty construction. See Chapter 6 for repair procedures. If sufficient coupling crews are available, coupling operations can be carried out in several sectors simultaneously.

Coupling on a downhill slope usually requires more effort than on a similar uphill slope. A highly trained crew can couple up to 2 miles per day of 6-inch pipeline over flat and clear terrain. The coupling crew should consist of seven soldiers. Their jobs differ depending if they use bolted or snap-joint couplings. When using snap-joint couplings, the crew consists of a crew leader, gasket greaser, front stabber, back stabber, coupler, coupler's helper, and a pinman. The crew will normally require the following tools and equipment:

- Two pipeline jacks.
- Assembly tool.
- Brass hammers.
- Drift pin.
- File.
- Two end caps.
- Half-gallon bucket filled with general agency agreement (GAA) grease.
- Cleaning rags.

Depending on the terrain and job assignment, the crews may need additional equipment, such as crowbars, brush hooks, axes, machetes, saw, shovels, hand auger, hatchet, large nails, long bolts, and crescent or open-end wrenches. The pipeline jacks, lazy boards, and wooden blocks are field-fabricated (Figure 5-4, page 5-10). All other tools come in the grooved-coupling, pipeline-construction tool kit or as part of the component packing list. To couple pipe--

(a) Grease the gasket lightly and place it in a clean location. Do this just before coupling the pipe ends together to avoid getting dirt on the greased gasket. (Dirt or sand on the gasket can cause the joint to leak under pressure.) Place the complete coupling assembly, to include the gasket, directly next to the joint to be connected.

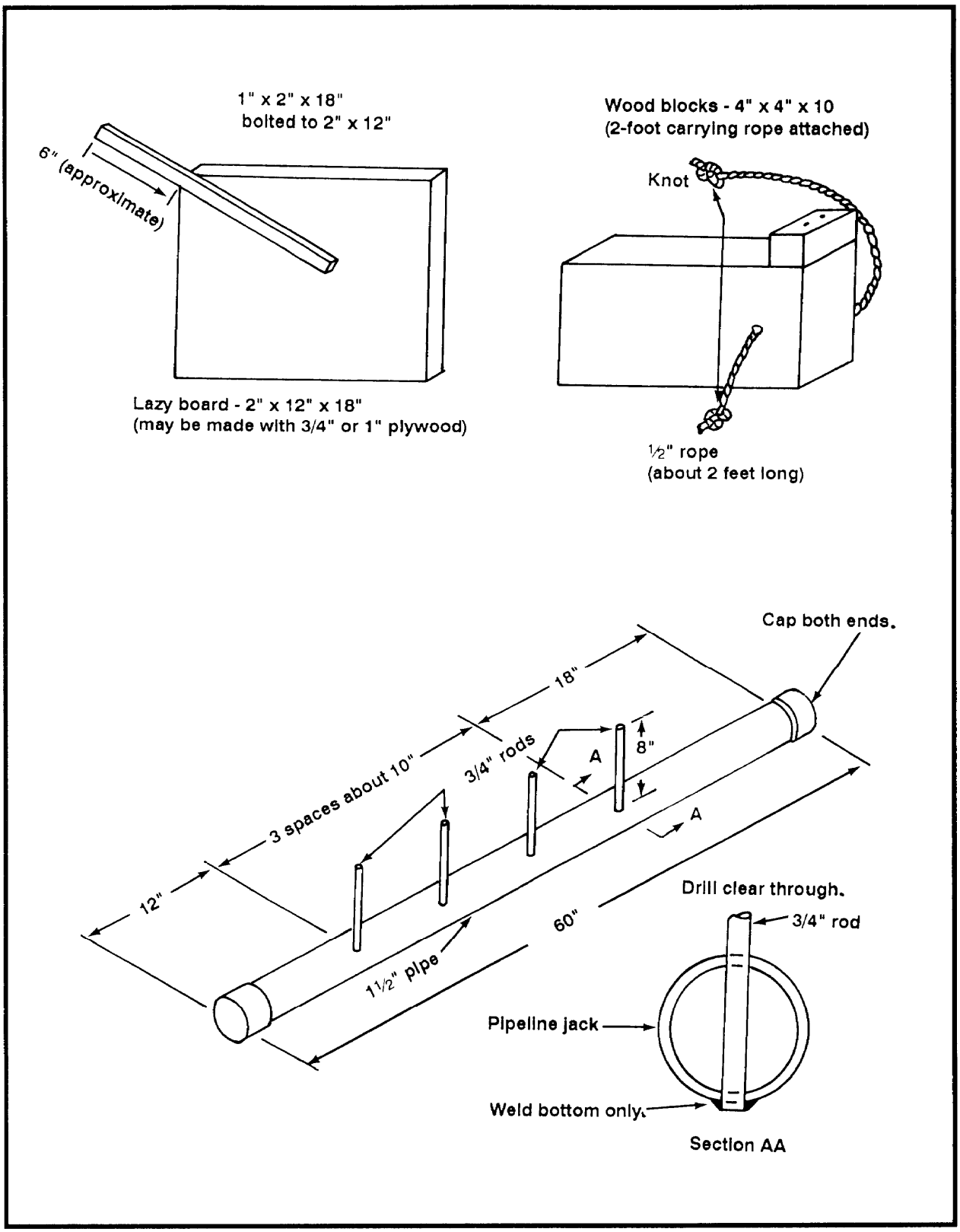


Figure 5-4. Pipeline jack, lazy board, and wooden block

(b) Place the greased gasket over one end of a pipe section you will join. Do not fold the inside gasket flaps over because a leak could result.

(c) Position the pipe ends together. It is important that you line up the pipe ends and that they remain in this position until you close the coupling completely. Unit-fabricated pipe jacks and wood blocks can make this task less strenuous. Figure 5-4 shows these two items.

(d) Adjust the gasket over both pipe ends centered on joint. Do not fold the inside gasket flaps over; the joint could leak.

(e) Seat the coupling in bottom grooves of pipe.

(f) Close the snap-joint coupling, or install the top half of a bolted coupling in the top grooves of the pipe. Make sure that you position the gasket properly inside the coupling and that the joints of the snap coupling are not pinching the gasket. A pinched gasket will ALWAYS LEAK and will require replacement. After the snap coupling is closed, but not pinned, you should be able to hold both of the hinges and rotate the coupling back and forth. Doing so will help position the gasket in the coupling.

(g) Close the coupling halves together completely. (On older couplings, use bolts; on newer couplings, use an assembly handle.) The assembly handle should close the coupling smoothly with minimal pressure. The assembly handle will not close easily if the gasket is positioned incorrectly inside the snap-joint coupling. If you feel resistance, do not force the handle shut. Reposition the gasket and try to close the coupling again. If repeated attempts do not work, use a new coupling. (During this procedure with the snap-joint coupling, the gasket is most susceptible to damage by pinching.)

(h) Insert a retaining pin in the closed hinge of the snap-joint coupling and drive the pin into place. A sparkless brass hammer is in each box of couplings. Use this hammer when fuel is in the area; otherwise, you can use a 3-pound hammer.

(9) Align the Pipeline. The relative position of one pipe length to the next is pipeline alignment. Because aluminum pipeline systems expand and contract, deflection must be less than 2 percent. This allows the pipeline to push and pull itself without causing undue strain on any joint. For example, 50 joints of aluminum pipeline increase in length by 15 inches with a 10O°F rise. The assembled coupling joint has a designed free deflection (without strain) of 4 percent. The installed deflection is limited to 2 percent, leaving room for some additional deflection during operation. You can field-fabricate coupling deflection templates to check alignment. If the ends of a two-length section are not outside each others radius, the pipeline is within required deflection tolerance.

You may have to use sandbags to level an aluminum pipeline system. (You do not have to level a steel pipeline system.) Place sandbags no closer than 2 feet from a coupling point. This allows for expansion and contraction. When stacking sandbags, make sure that they will not fall over during pipeline movement. To stack sandbags properly, build a large base and workup to a small top where the sandbag meets the pipeline. Avoid stacking sandbags higher than four levels. Properly grading the pipeline route before construction starts can save time and manpower when leveling.

(10) Anchor the Pipeline. Because anchoring is not a manpower-intensive task, a long length of pipeline is constructed before anchoring is required. The anchoring crew is usually a two-soldier team. They should anchor every 1,000-foot section of aluminum pipeline midway between the expansion loop. Doing so allows for expansion and contraction due to tempemture and pressure. Paragraph 5-2b discusses expansion devices. The crew installs a screw-type anchor (Figure 5-5) using a hydraulic drivehead attachment that can be put on a JD410 or a SEE boom. The coupling-crew leader should establish a method of marking the pipeline for anchor installation. After installing the anchor, the crew connects it to the pipeline with a metal clamp lined with a piece of rubber. They must be careful not to move the pipeline out of alignment during the anchoring procedure.

(11) Fill and Test the Pipeline. Before fuel pumping starts, military pipelines must be inspected and pretested to locate and repair leaks, obstructions, and other flaws in construction. Fuel could be wasted if this procedure is not followed. For example, 1 mile of 6-inch pipeline could lose about

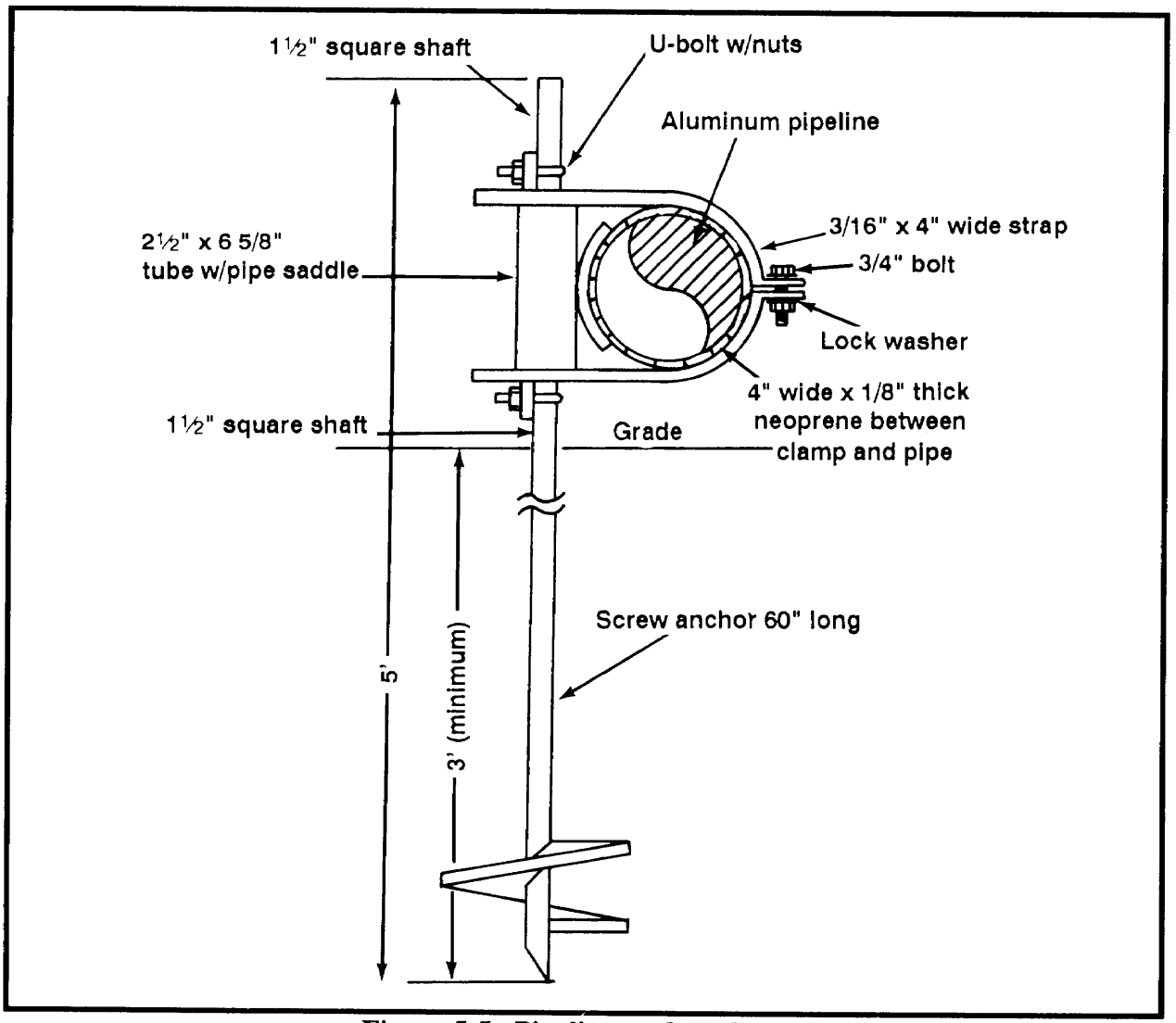


Figure 5-5. Pipeline anchor clamps

210 barrels (bbl) of fuel even if valves were closed immediately after a leak occurred. Because of the required equipment and safety precautions, repairing a full fuel line is more difficult than repairing an empty one.

(12) Clean and Pack the Pipeline. As soon as possible after testing, clean the first major portion of the pipeline inland from the coast and pack it with fuel. (It may take several days for fuel to reach the first inland pipe head or terminal.) Cleaning the line not only removes dirt, small stones, and other foreign material but it also helps reduce flow resistance and the pumping effort required to produce rated flow through the line.

To clean the line, pass three or four scrapers through it, as time permits. The water should drain into an impounding basin and all solid material be allowed to settle out. Do not divert the water into nearby streams because the water could harm or kill livestock, fish, and other marine life that drink from the streams. Once most of the debris settles, either reuse the water to test the next section of line or gradually drain it off into the natural drainage system.

Pack the line by sending a line scraper just ahead of the fuel to reduce the mixing of the water and fuel when they meet. In cold climates, send several scrapers through the line to ensure that the line is free of water. Some water will remain in the bottom of the gasket cavity of each coupling but will gradually work its way down the line. Running scrapers through the line just before subfreezing temperatures (20 to 25°F) will prevent ice crystals from accumulating and plugging the line. (The Alaskan pipeline had problems with these crystals accumulating in low spots, valves, and other locations that blocked the flow through the pipeline.)

b. *Expansion and Contraction of Coupled Pipelines.* Surface-laid metallic pipe expands and contracts with changing temperatures. Groove-type couplings provide some angular deflection and slack adjustment between each pipe joint (Figure 5-6). Because aluminum expands and contracts more than steel, control devices (expansion loops) are required to relieve the tension in the pipeline caused by thermal expansion and contraction. Aluminum pipeline is anchored every 1,000 feet, and an expansion device is installed in the center of every 1,000-foot section. The maximum expansion with a differential in temperature of 100 degrees can be as much as 15 inches. The U-loop and Z-loop are two types of expansion devices (Figure 5-7, page 5-14).

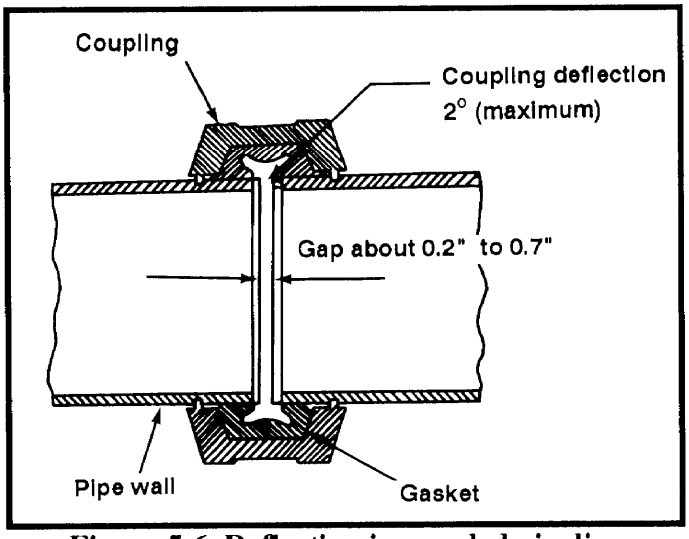


Figure 5-6. Deflection in coupled pipeline

- The U-loop is constructed with three 19-foot pipe sections and a combination of 45- or 90-degree elbows.
- The Z-loop is constructed with a 19-foot pipe section offset and 45-degree elbows.

5-3. Hose-Line Systems. The US Armed Forces use hoses extensively in water and petroleum transportation. They can be laid much faster and with less effort than a

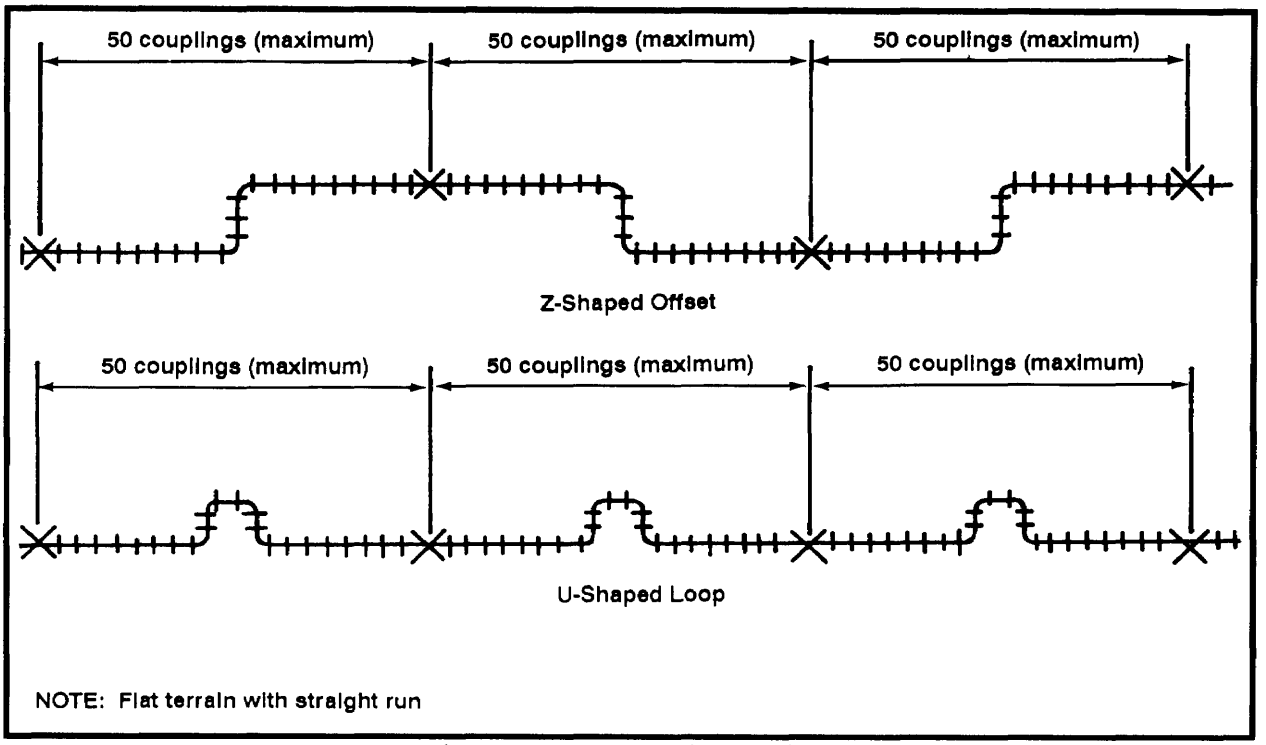


Figure 5-7. Expansion devices

metallic pipeline. Hose lines do not require extensive cribbing, staking, expansion joints, or other stabilization efforts as metal pipeline systems do. That factor saves time. However, the disadvantages of using hoses are low allowable working pressure, reduced shelf life, and less durability. Because of the low working pressure and the durability problem, hoses usually are used only within TPTs and as a temporary extension or lateral from a rigid pipeline no greater than 5 miles long.

New technologies are addressing the disadvantages of using hose. Durability has been enhanced and working pressures increased so that a hose pipeline is a viable alternative. The OPDS has a MAWP of 740 psi. The shelf life of new hose is currently under investigation. Hoses are connected using either a cam lock or a grooved-type (single or double) coupling clamp. Connecting devices will be discussed later in this chapter.

a. *600-Foot, 6-Inch Hose-Reel Assembly.* This system is an upgrade to the 250-foot, 6-inch lightweight hose (stored in flaking boxes). The hose-reel system consists of 600 feet of 6-inch lightweight hoses packaged on reels, with two reels mounted on a skid. The MAWP is 150 psi. The hoses do not have attached connecting ends. They will be attached, using a bolt-on-type clamp at assembly time. (Figure 5-8 shows bolt-on-type clamps.) The hose line is manually deployed and has a 24-volt, direct-current, hydraulic power pack for recovery. Six reel systems (two 600-foot reels per system) and one power pack can fit into one ISO container. The reel system eliminates the bending and stressing of the hose and increases the storage life 1 1/2 to 2 times longer than the hoses that are stored in flaking boxes.

b. *4-Mile OPDS.* This system, with the SALMS, provides rapid delivery of petroleum from offshore tankers to the shore high-water mark (Figure 5-9, page 5-16). The system, which is

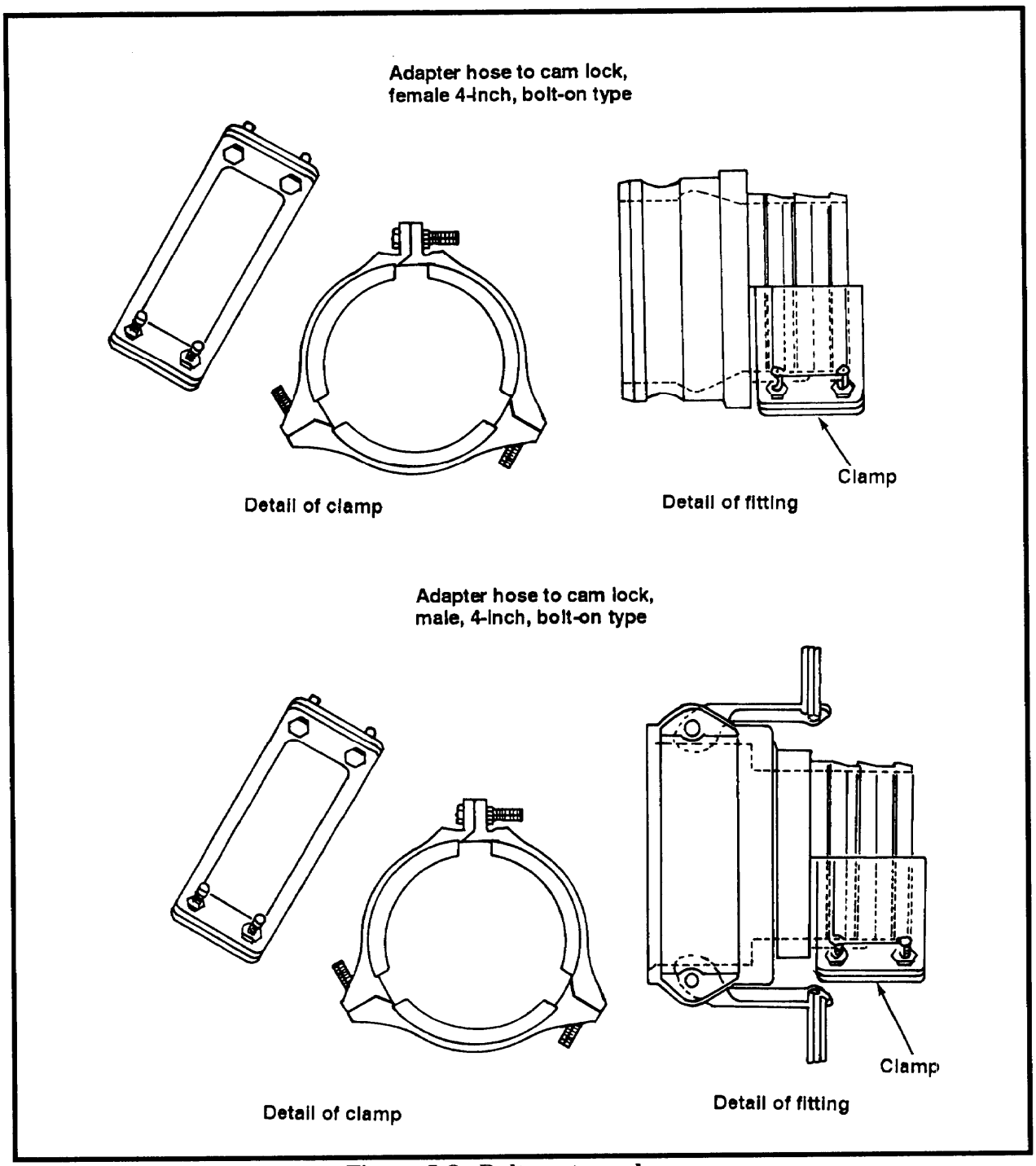


Figure 5-8. Bolt-on-type clamps

constructed by the Navy, uses high-pressure hoses on ship-mounted reels. Each reel holds 0.5 mile of collapsible hoses; eight reels make up the 4-mile kit. Hose-to-hose and hose-to-fitting connections are made with 6- and 12-bolt flange connections that are designed for a burst pressure of 2,200 psi. The 6-inch diameter and 1-inch-thick hose has a MAWP of 740 psi. The hose can be stretched to 33 percent under conditions of use. Petroleum is pumped using two positive

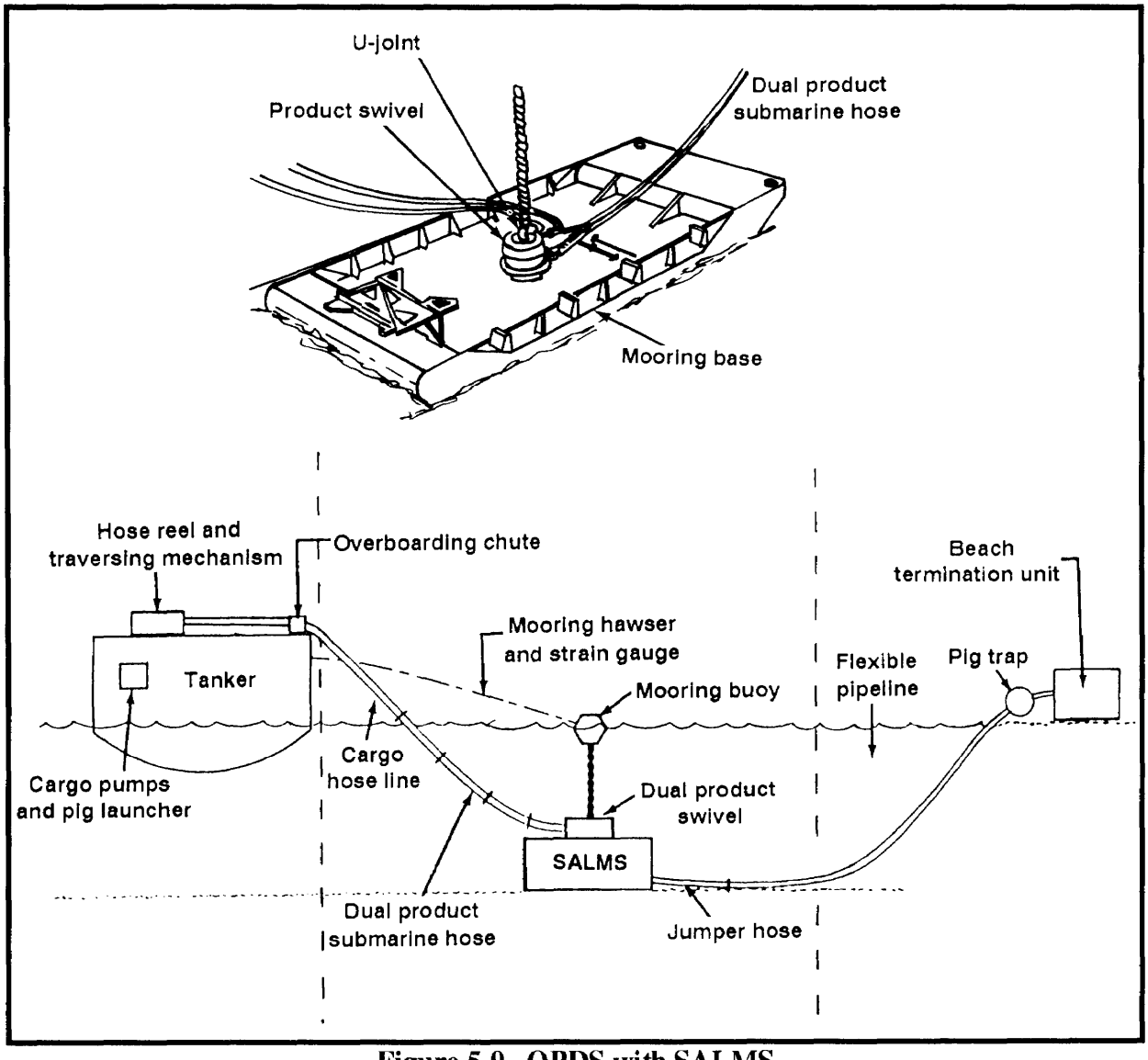


Figure 5-9. OPDS with SALMS

displacement pumps in parallel (500 GPM each at 700 psi). High pressure is required by the high head losses that result from delivery of 1,000 GPM in the 6-inch hose over the 4-mile (maximum) distance to shore.

c. *50- and 500-Foot, Lightweight, Collapsible, Discharge, 6-Inch Hoses.* These hoses have a MAWP of 150 psi. The 500-foot hose is packed two per flaking box and is part of the transfer hose assembly. The 50-foot hose is available individually and is used in the tanker-truck receipt and switching manifolds, tank-farm and fuel-dispensing assemblies, and contaminated-fuel module.

d. *12-Foot, Noncollapsible, Suction, 6-Inch Hose.* This hose is used in the tank-farm assembly and tanker-truck receipt manifold.

e. *12-Foot, Noncollapsible, Discharge, 4-Inch Hose.* This hose is found in the contaminated-fuel module and the 50,000-gallon, TPT, optional-tank configuration.

f. *Collapsible, Dispensing, 1-,1 1/2-, 2-, and 4-Inch Hoses.* These hoses are used in the fuel-dispensing assembly and the 50,000-gallon, TPT, optional-tank configuration. The 4-inch hose is available in 25- and 50-foot lengths. The 2-, 1 1/2-, and 1-inch hoses are available in 25-foot lengths.

g. *12-Foot, Suction, 4-Inch Hose Assembly.* This hose is used in the tanker-truck receipt manifold; contaminated-fuel module; and the 50,000-gallon, TPT, optional-tank configuration.

5-4. Pipeline and Hose-Line Obstacle Crossing. Points where military pipelines and hose lines cross roads, railroads, watercourses, or any other obstacle require special treatment. When possible, bypass obstacles. If this is not possible, with minimal effort, construct an obstacle-crossing device. It is a good practice to anchor a pipeline at each end of an obstacle crossing and, if the site is susceptible to damage, install a gate valve at each end. Constructing obstacle-crossing sites should take place before pipeline construction reaches that site. This eliminates the need for pup joints and increases the rate of pipeline construction. The most commonly encountered obstacles and ways to negotiate them are discussed below.

NOTE: For discussion purposes, metallic pipelines and hose lines are referred to as pipelines.

a. *Road and Railroad Crossings.* Roads are the most commonly encountered pipeline obstacles. Crossings can be made by running the line through existing culverts. If existing culverts are too far from the pipeline route, install underground culverts using either larger pipe or nestable culvert material. Encase the pipeline in culvert material for protection as well as convenience in installation and maintenance. (When time is a factor, use large diameter pipe or a metal sleeve instead of nestable culvert.) If you use nestable culvert, assemble it in advance and haul it to the job site. When you use an existing culvert, the pipeline will reduce the culvert's cross-sectional area and restrict the water flow. If drainage water contacting the pipeline is a factor, anchor the pipeline so it cannot be swept away. Pipelines crossing culverts require the same amount of cover as a culvert installed for drainage purposes.

(1) Culvert Size. A culvert 4 inches larger in diameter than the pipeline will provide sufficient clearance for the pipeline. If possible, prevent the pipeline from contacting the culvert by supporting it with sandbags (Figure 5-10). Anchoring the pipeline at each end of the culvert is best.

(2) Culvert Installation. The opening for the culvert may be made by boring, tunneling, or digging a trench wide enough to receive it. The method used will depend on the type of soil encountered and the available equipment. The most common method is the ditching method. If you use this method, make sure that there is sufficient cover and that it is thoroughly compacted.

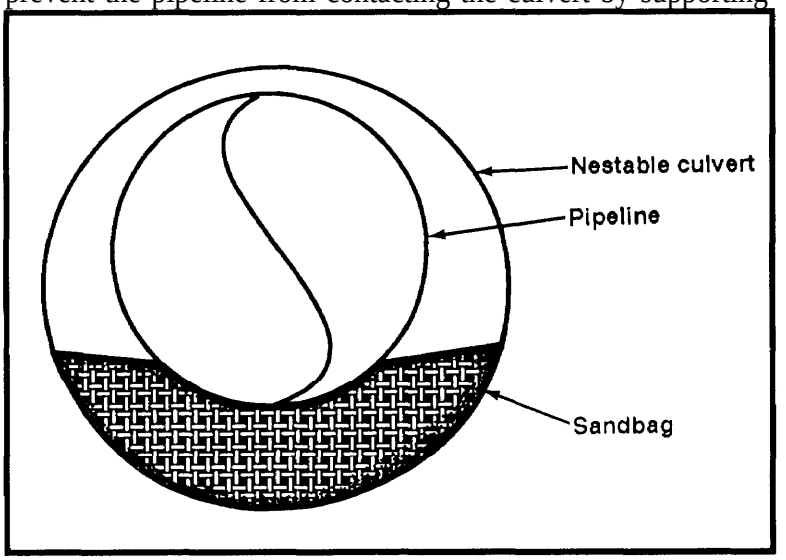


Figure 5-10. Pipeline in a culvert supported by sandbags

b. *Stream, River, and Ravine Crossing.* When possible, use existing structures to cross streams and rivers. If you use an existing bridge, the pipeline will be a more lucrative target. Also, you will have to protect the pipeline from vehicular damage. If an existing structure is unavailable or if the tactical situation is not advisable for pipeline use, construct a crossing device. Do this by either laying the pipeline in a trench at the bottom of the stream or by installing an overhead pipeline that crosses at a site away from (usually downstream) an existing bridge. The method you use will depend on the tactical situation and the conditions that each obstacle presents.

(1) Overhead Crossings. Often a small stream, canal, drainage ditch, or ravine must be crossed above ground when laying coupled pipelines. If the width is too great for an unsupported span (19 and 40 feet for aluminum and steel-coupled pipelines, respectively), you must construct a crossing device. Sometimes, a critical gap structure may be set in the watercourse. If this is not feasible, then the pipeline must be supported by a suspension structure. The critical gap structure and various size suspension-bridge kits are available through AFCS. If the kits are not available, you will have to construct an improvised structure.

(2) Suspension Bridges. Pipeline suspension bridges are prefabricated and packed in kits for 100-,200-, and 400-foot spans (Figure 5-3, page 5-7). The bridge kits are available through AFCS. Detailed assembly instructions come in the packing list for each kit. Installation procedures for the suspension bridges are as follows:

(a) Choose a crossing site. However, remember that the difference in height between banks must be less than 8 feet. If it is not, you may have to cut one bark with a bulldozer. Do not use a filled area as a tower-base location.

(b) Unpack all assembly parts. Make sure that all the required parts are on hand, and learn to identify them.

(c) Set the tower base in position, using a 20-ton crane, and stake it down.

(d) Assemble the tower by attaching the required fixtures. Erect the tower using a 20-ton crane.

(e) Attach guy wires to the tower assembly and secure them to ground.

(f) Place a 12-inch-diameter pipe deadman on each shore and attach each to a tower assembly.

(g) Attach all cables with *U* -bolt wire clamps.

(h) Position staging boards to cross bearers.

(i) Attach the tension cable to the cross bearers, parallel with the staging boards.

(j) Attach two wind guys per shore to cross bearers. Secure them to each shore.

(k) Secure 1/4-inch cable with *U* -bolts to the suspenders.

(1) Construct the pipeline on the bridge from the center to each shore. Position the coupled joints midway between the cross beams. Secure the pipeline to the cross bearers and staging planks with pipe straps.

(m) Use cable turnbuckles to achieve uniform tension on all cables.

(3) Critical Gap Structure. This structure is available through AFCS and is used for crossing small streams and gullies. It is made up of 4-inch-diameter steel tubing, angled steel, and roller assemblies (Figure 5-1, page 5-5). The rollers are installed so the pipeline can move during expansion and contraction. The structure is field-fabricated on-site with welding equipment. Each structure is placed at an interval equal to the length of a stick of pipe, with the coupling positioned directly between the structures.

(4) Improvised Structures. Figure 5-2 (page 5-6) shows improvised methods of supporting short spans of unsupported pipeline. In emergencies, you can use damaged or demolished bridges or floating footbridges (Figure 5-11, page 5-20) to carry a pipeline. However, construct alternate lines as soon as possible. This is especially true when lines are carried on floating bridges that are unstable and subject to hazards from floods, floating debris, derelict boats, and floating explosive charges placed by enemy partisan forces.

5-5. Pumping Stations. Pumping stations are located along the pipeline trace based on the hydraulic design of the system. They consist of the required pumps and the operating and living facilities for the operating crew. Operating crews are responsible for their own facilities.

The pumping station is made up of a launcher, receiver, and strainer and the pumps connected by pipe. For an aluminum pipeline system, a standard pumping station is made up of two 800-GPM pumps. Pumping stations can be built to any specification. However, they must have the ability to remain operational even when pumps are shut down for maintenance or replacement. Pumping stations are designed to be operational 24 hours per day. A trained engineer squad can construct a standard pumping station (steel or aluminum pipeline system) in one day if given the proper material handling equipment and a prepared pump pad. The material-handling equipment will differ depending on the type and weight of the pumps being installed.

a. *Site Selection.* Many factors are considered when selecting a site for a pumping station. The site--

- Must be located within the limits of the hydraulic design. If an adjustment is required, it should be towards the source of the fuel, not the demand. This will ensure that sufficient suction pressure is available at the pump.
- Must be in an area that is large enough to set up the station. The number of pumps at the station will determine area size.
- Must be level and strong enough to support the weight of the pumps. Existing facilities such as parking lots and abandoned slabs should be used, if available.
- Should provide access for installing and removing pump units without interfering with piping.
- Should provide for radio communication.
- Should allow any spilled fuel or vapors to drain away from the pumping station and not gather in low pockets in the surrounding area. The station's fuel-supply storage tanks should be located to ensure proper gravity flow to the pumps. Fuel vapor is heavier than air, so vapors settle near the ground and flow downhill. Vapor pools form in low areas unless dispersed by the wind. These vapor pools present fire and explosive hazards.

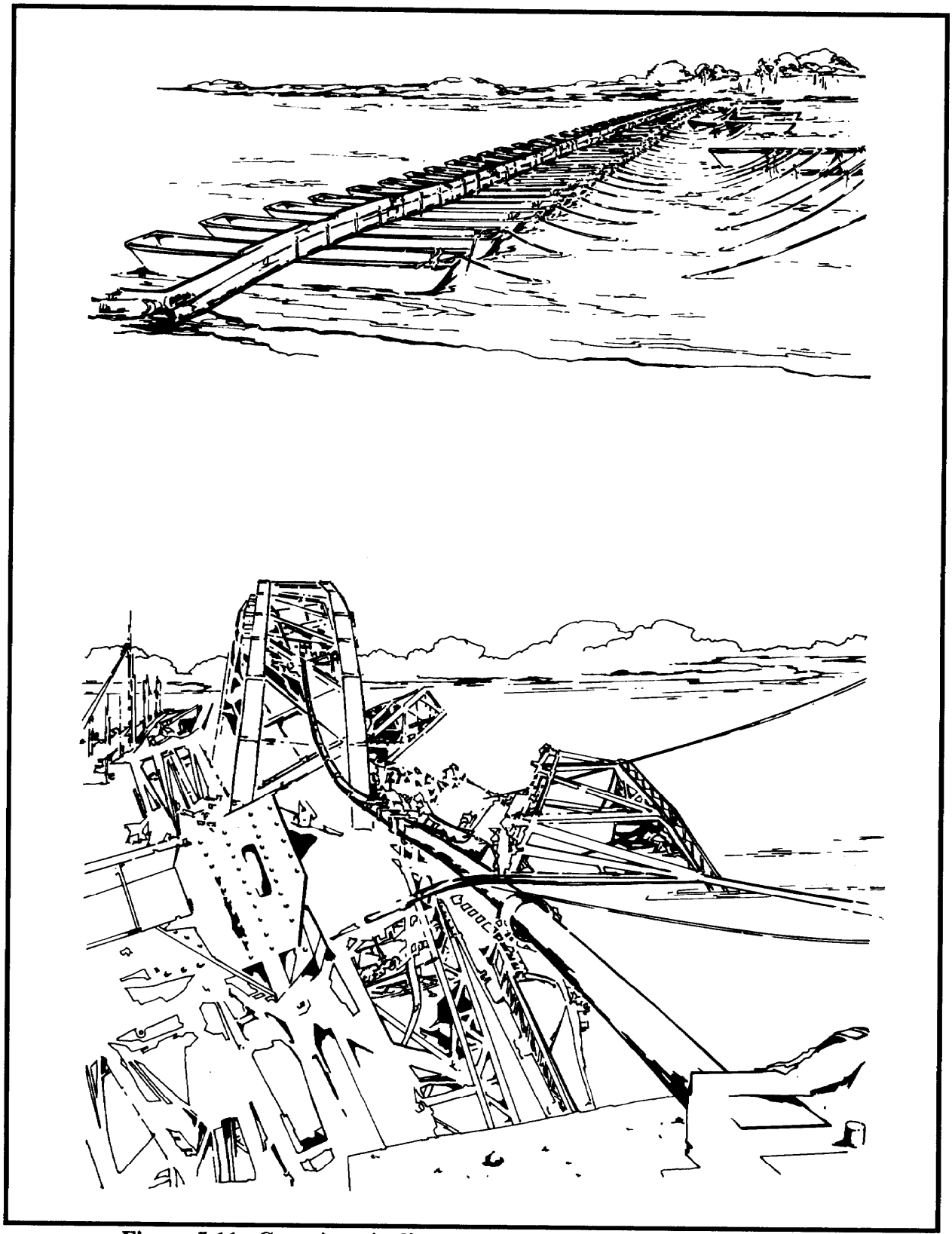


Figure 5-11. Carrying pipeline on a demolished bridge or footbridge

- Should make use of natural cover and concealment, thereby reducing the amount of artificial camouflage needed if the tactical situation dictates.
- Should have room for the operating crew to set up living and operating facilities. Crew members usually live intents unless structures are available on-site.

b. *Pad Construction.* The pumping-station pad must be within 5 degrees of level or pumping-unit damage will occur during operation. A level pumping-station pad makes it easier and less time-consuming to assemble the piping that connect the pumps. In a level area, you can predetermine the size and number of pup joints you need and precut these joints. (Precutting pup joints eliminates the need to measure and cut them on-site.)

The area required for a standard pumping-station pad is 136 by 58 feet for the aluminum system and 80 by 16 feet for the steel system. The pad can be constructed of concrete or gravel and must support the weight of the pump units. The site should provide access for installing and removing pump units without interfering with piping. A berm is constructed for the fuel-supply storage tanks. Figure 5-12 shows a standard pumping-station layout, aluminum system.

c. Standard Pad Layout. Accurate pumping-station pad layout will ensure that the pump units are positioned so that precut, nonstandard lengths of pipe can be used in assembling the piping between pumps. Assembly time is increased if pup joints are measured and cut on-site. Layout is normally done with stakes and string. Pumps must be situated to allow trucks and material handling equipment ready access without interference with piping and manifold. This enables pumps to be exchanged after the station in built. Pumps are positioned parallel to one another exactly 33 feet 3 1/2 inches apart on center (Figure 5-12).

d. *Pump Placement.* Pump units should be moved directly from the main issue point to the pumping-station pad. This eliminates unnecessary lifting and loading operations at construction

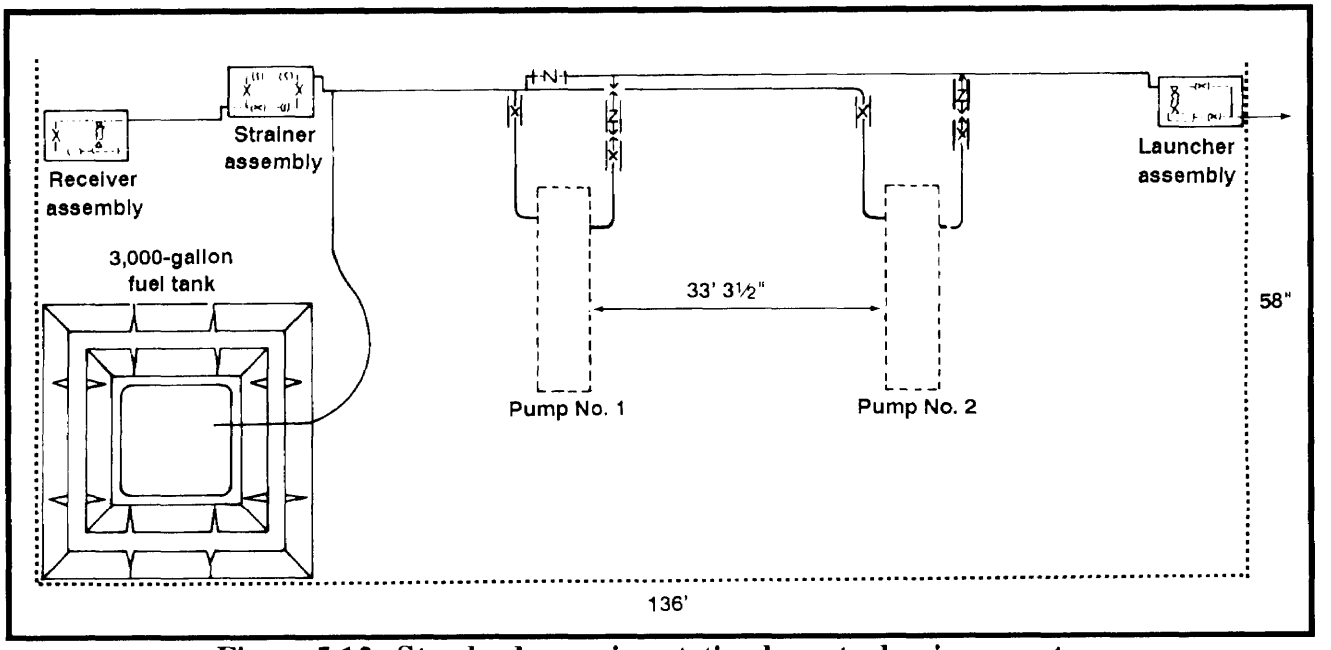


Figure 5-12. Standard pumping-station layout, aluminum system

staging areas. A 40-ton, rough-terrain crane and a low-bed trailer are required for loading, moving, and placing each 800-GPM mainline pump unit. When placing pumps, the crane boom will be extended, so the maximum lifting capacity cannot be used.

e. *Pumping-Station Construction Checklist.* Consider the following when constructing a mainline pumping station:

- Pad construction, completed.
- Pump-pad layout, completed.
- Pup joints, precut.
- Pumps, positioned on pad. All transportation and lifting support scheduled for mainline pumps, shelters, receiver, launcher, and strainer.
- Pumping units, reprocessed. Pump units that are received from war stocks or that are new must be reprocessed before operating them. This includes installing and aligning the engine to the pump coupler, filling all fluid reservoirs, running the engine for break-in period, and calibrating all gauges. The operator's manual for the 800-GPM mainline pump is TM 5-4320-307-10.
- Suction and discharge manifolds on each pump, installed. These are steel and are bolted to a flange on the pump unit.
- Pipe and valves connecting pumps, installed. After pump units are positioned, the suction and discharge manifolds are installed on each pump.
- Strainer, launcher, and receiver, placed and connected, These items are placed with the 7 l/2-ton crane and connected to the system.
- Auxiliary fuel source, placed and connected. The 3,000-gallon fabric tank and liner is installed with a berm around it.

5-6. Testing Pipeline Systems.

a. *Responsibility.* The commanding officer of the unit that constructed any given segment of the pipeline is responsible for coordinating the testing and inspection of his unit's work. The constructing and operating units conduct the testing and inspection. Turnover will take place when the certificate of operability is signed. If inspection and test results are not within established standards, the commander of the operating unit may reject the line as unsuitable for operation.

b. *Certificate of Operability.* After the pipeline is tested, inspected, and found to be constructed to standard, the operating unit prepares an operability certificate and forwards it to the constructing unit and higher headquarters. The commanding officers of the constructing and operating units sign the certificate. The certificate contains--

- A statement as to the operability of the line and its acceptance by the operating unit.
- The section and mileage of the line tested.
- The standard to which the line was built and tested.
- The testing pressure.
- The test method and duration of the test.

c. Measuring Pressure. To test a section of pipeline, place a pressure gauge at each end of the section. The test-section ends are normally at the pumping-stations. With the aluminum pipeline system, mount a pressure gauge on the launcher and receiver assemblies, which are used as the ends of the test section. In the steel pipeline system, mount a pressure gauge in the vent-plug tap of an overcoupling clamp (Figure 5- 13). To install the clamp and gauge device in the steel system, loosen the coupling at a joint and remove the gasket to cause a temporary leak. Retighten the bolts on the coupling and fasten the clamp and gauge device over the coupling.

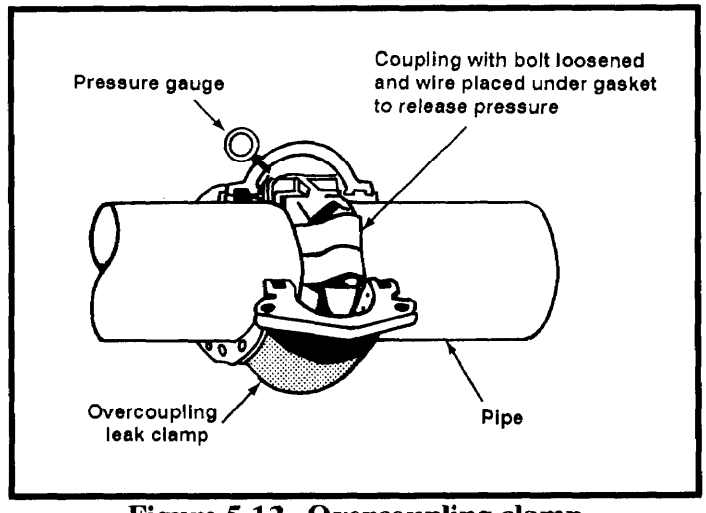


Figure 5-13. Overcoupling clamp

d. *Hydrostatic Testing (Fill and Test).* Military pipelines may be tested in long or short sections with water (and under special circumstances with fuel) using the pumping stations to develop the necessary pressure.

(1) Using Fresh Water. Because of safety and economy, fresh water is preferred. The water should be as clean as possible, but it does not have to be potable. If the water is very muddy, pump it into a temporary impounding basin and let the silt settle out. You may have to construct a temporary pipeline or hose line from the water source to the pipeline. Also, if the flow rate at the source is not sufficient, you may have to construct an impounding basin so that sufficient water can be collected in advance. Fresh water may be too difficult to obtain in sufficient quantity in tidewater areas. If possible, pump freshwater from an inland source backwards through the pipeline to the marine terminal area by making a temporary change in the pumping station's piping system.

(2) Using Salt Water. If you do not have sufficient quantities of fresh water, you may use salt water. Once you complete the fill-and-test procedures, flush the line several times with clean fresh water, if possible, separated by pipeline cleaners, before packing or filling the line with fuel. Salt water will--

- Not adversely affect the fuel any more than dirty freshwater.
- Ultimately be removed by filter/separators at dispensing stations.
- Not cause significant corrosion inside the steel pipe, when used only once in testing.
- Be removed by the pipeline cleaners used in flushing the pipeline and initially packing the line with fuel.

The inside surfaces of steel-tubing sections from military storage depots will normally be corroded and contain some dirt. Swabbing the sections once during pipeline construction will only remove sticks, dirt clods, stones, scaly rust, reptiles, and so forth. Proper cleaning requires swabbing the pipeline several times. It also ensures the removal of all air from the pipeline. Do not use fresh water to test the pipeline in prolonged subfreezing temperature or if you cannot remove the water

using pipeline cleaners. Pack the line with fuel before subfreezing weather. If you use ocean salt water (freezing point about 27.5°F), you can test the line at a lower temperature than if you use fresh water. If necessary, add salt or calcium chloride to the water to lower its freezing point.

(3) Using Fuel. Testing with salt water is preferable to testing with fuel. Test with fuel only as a last resort in an extreme emergency, when no water is available or when extremely cold climatic conditions make hydrostatic testing with fresh water or salt water impractical. If you must use fuel, use diesel (or jet) fuel, since it is less volatile and less toxic than leaded gasoline. Testing with fuel will normally delay completion and operation of the pipeline, even if you take proper safety precautions.

When using fuel, tank trucks and fire-fighting equipment must be available for draining the line sections that leak. Make sure you have plenty of overleak couplings to temporarily correct small leaks. Before testing, install a *T* and a valve at the bottom of long slopes, as a temporary measure. Doing so will make draining the line easier and allow you to attach a hose line or pipeline to tank trucks to receive the fuel.

Do not let the fuel drain onto the ground or into roadside ditches or streams. To do so not only creates a serious safety hazard but also results in air, water, and ground pollution and can result in vegetation, livestock, wildlife, water-fowl, and marine-life destruction. The US Government could be financially responsible for such damages. Because testing a pipeline with fuel presents many hazards, the noncommissioned officer in charge (NCOIC) or officer in charge (OIC) should try to get written orders before proceeding with such tests. If you have to drain fuel at a point where a *T* is not installed, do the following:

- Dig a pit large enough to contain all the fuel.
- Construct dikes, if necessary.
- Line the pit with a tarpaulin to minimize contaminating the fuel and the ground by each other, if possible.
- Anchor the line securely on both sides of the coupling you are to remove.
- Have spare piping sections available in case the coupling suddenly slips out of the grooves and damages them as you loosen the nuts. Be careful because loosening a coupling at the bottom of a long slope that may be under a large hydrostatic head is dangerous. The two ends of the line may whip about and create sparks. Fuel may spray several feet in an unpredictable direction. Spraying liquid under several hundred pounds of pressure can seriously injure the eyes.
- Make sure that fire-fighting equipment is readily available.
- Make sure that an explosive-vapor detection meter is available.
- Have a pneumatic sump pump and tank truck standing by to recover fuel.
- Test pumping-station manifolds to ensure that no leaks will occur because of inherent hazards present at pumping stations. Such hazards could be hot exhaust stacks, sparking generator brushes, electric light bulbs and electric generators, violators of *No Smoking* regulations, and passing vehicles.

(4) Criteria.

(a) Communication. There must be reliable communication at the start point of the pipeline, between the pumping stations, and at the end of the test section. All pumping stations must be able to communicate with the fuel dispatcher, who controls the entire system and may be hundreds of miles away. Long-range amplitude modulation radios must be at each pumping station before starting fill-and-test procedures. Also, the quartermaster branch pipeline operating units must have these radios for operating the pipeline. Pipeline operating units have the required AM radios in their modification table of organization and equipment (MTOE). Crews that examine the pipeline test section must have communications among themselves. Short-range frequency modulation radio sets, within the constructing unit's MTOE, are used between the test-section inspection crews.

(b) Calibration. All pressure gauges must be calibrated before testing. A deadweight tester is used for this purpose.

(c) Inspection. The inspecting crew members must be dependable and have good sight and hearing. Double checking and strict supervision of the inspecting crew are essential. An undetected leak may require shutting down the line for many hours and spending thousands of man-hours and equipment hours repairing and repacking the line with fuel. Mark leaks so that they can be identified for future repair. Inspecting crews should categorize leaks and measure the loss as accurately as possible, such as the number of drops per minute.

(5) Procedures.

(a) Inspect the pipeline test section to ensure that all vent and gate valves are open. Vent valves are located on hilltops and opened to drain air from the pipeline system. Gate valves must be completely open or they will restrict the passage of the line scraper.

(b) Begin pumping the test medium from the pumping station at a rate of 300 GPM. Maintain this rate by opening or closing the discharge valve on the pump unit. A crew will walk with the scraper, monitoring its exact location.

(c) Insert a line scraper to ensure that all air and any debris are pushed out of the line, after pumping about 3,000 gallons. Crew members (also called *pig walkers)* will close the vent valve as the scraper passes the valve and a steady stream of test medium is flowing. They will monitor the exact location of the scraper and maintain radio contact with the dispatcher at the closest pumping station. If fuel is used as a test medium, a collection plan must be followed to capture the fuel.

(d) Isolate the line by slowly closing the launcher, receiver, or gate valve as soon as the scraper reaches the end of the test section. Open the initiating pump-unit vent valve, slightly, at the pumping station producing the pressure or the gate valve at the end of the test section. This will prevent the pump from overheating and will not affect attaining the test pressures. The pumping-station operator can easily detect the proper flow rate to prevent overheating by placing one hand on the pump casing and the other on the inlet pipe. There should be no significant difference in temperature.

(e) Increase the discharge pressure of the initiating pump to the desired test pressure (Table 5-2, page 5-26), normally using 50-psi increments. It takes about 2 to 3 minutes for each 50-psi

increase. Coordinate this throttling process by telephone or radio with the dispatcher. As pressure is increased at the initiating pumping station, it should also increase at the end of the test-section pressure gauge. If this pressure increase does not occur, there is either a major leak or an obstruction in the line. Shut down the line immediately and inspect it.

Table 5-2. Pipeline test pressures

Component Description	Test Pressure (psi)
Welded pipe	
4-inch	2,500
6-inch	
0.219-inch thick	1,800
0.280-inch thick	2,250
8-inch	
0.250-inch thick	1,500
0.322-inch thick	1,950
0.375-inch thick	2,100
Coupled pipe	
Standard-weight steel	
4-inch	1,500
6-inch	1,500
8-inch	1,200
Lightweight steel	
4-inch	900
6-inch	900
8-inch	750
Lightweight aluminum	
6-inch	740

(f) Close off the test section at the initiating pumping station using the launcher assembly or a gate valve as soon as pressure has built up. Immediately decrease the discharge pressure of the initiating pump and take it off-line.

(g) Inspect the test section and mark leaks. Leaks are detected by sight or by feel. Slight leaks can often be eliminated by shaking the joint. To do this, place a pick handle, crowbar, or similar lever under the coupling and lift the coupling quickly several times. If you cannot correct small leaks at couplings, mark the couplings and estimate the quantity of the leak. If a large leak occurs, shut down the pumping station, temporarily install an overleak clamp, and resume testing. Locate all leaks before emptying the line to make repairs. While the leaks are being marked, the line pressure is monitored at each end.

(h) Repair and retest the line until it meets the standards established by higher headquarters. If you cannot drain the line before repairing, isolate the area to be repaired by closing the nearest gate valve in each direction. If fuel has been used as a test medium, drain the fuel into a suitable container before starting any repairs. Make sure that the line is not under pressure during repair. Repair all leaks by replacing the defective pipe section, coupling, and gasket. Continue testing the entire pipeline.

DANGER

Removing a coupling on a high-pressure line could result in severe injury or death.

e. *Compressed-Air Testing.* Do not use compressed-air testing for high-pressure overland pipelines. A line failure under a high-pressure air test would be an explosive failure since the compressed air within the pipe would be rapidly released. Liquids are incompressible and are, therefore, safer test media.

Air testing will produce many leaks that will not occur with water or fuel testing. Water or fuel may dissolve and wash away small pieces of dirt underneath a gasket, which will then seal; air will not. Many gaskets, especially old ones, will not seat or seal initially under low pressure. With air testing, you will have to perform an initial cleaning and flushing of the line with water and pipeline

cleaners to remove residual dirt and rust before the line is packed with fuel. Otherwise, a large amount of fuel will be contaminated, and an unnecessary load will be placed on the sand traps and filter/separators to decontaminate the fuel.

Although hydrostatic testing of sections of welded pipelines for tanker unloading during the onshore construction phase is best, air testing is relatively safe and reliable. Submarine pipelines are weight-coated (to make them heavy enough to remain on the bottom) and therefore are not likely to whip about even if a welded joint should fail suddenly and completely. Also, 110-psi air pressure is equal to or slightly greater than the normal pressure of 100 to 110 psi that tanker captains will allow on their pumps.

Using soapy water to detect leaking couplings is tedious, time-consuming, and difficult. You must apply soapy water to both sides of the coupling and to the two joints between their ends and watch for leaks. To do this, you have to lift each joint about 1 foot or more off the ground so you can apply the soapy water to the underside of the coupling and watch for air bubbles.

f. *Locating Obstructions in a Pipeline.* If the pipeline has been properly and carefully constructed, no obstructions should remain. However, when tests show a pressure drop at the far end of the test section or an increase in pressure at the initiating pump, an obstruction is probably present. The easiest way to locate the obstruction is to use a scraper. Insert the line scraper upstream from the obstruction. A walking patrol will follow the scraper until it stops. The line is then shut down and the obstruction removed.

Chapter Six. Maintenance and Repair

6-1. Responsibilities. This chapter explains the maintenance and repair of military pipeline systems for which engineer units may be responsible. The commanding headquarters of the constructing and operating units define what repairs are considered minor and major, based on the specific tactical situation. Quartermaster units are responsible for minor repairs and organizational and limited higher-echelon maintenance on a constructed pipeline system. Engineer units are responsible for major repairs when special engineer equipment is required and for organizational maintenance to put the system into operation. See FM 10-20 for details on the maintenance of pipeline systems.

a. *Operator Maintenance.* The person responsible for the day-to-day care of equipment performs operator maintenance, which is done before and during pipeline operations. Most operator maintenance is preventive maintenance. For example, the operator inspects the pumping equipment for leaks and for signs that the equipment needs adjusting or repairing. He must read the technical manuals for the equipment to be swam his repair responsibilities. The operator performs those actions that are within the limits of his capabilities and duties. He reports defects that he cannot correct to his supervisor. The operator also knows the normal operating characteristics of the equipment. For example, he should be able to tell when the equipment is making more noise than usual and when readings are not within normal operating limits.

b. *Organizational Maintenance.* The organization responsible for the operation and upkeep of the pipeline and related equipment and facilities performs this type of pipeline maintenance. organizational maintenance--

- Is service and repairs that authorized unit personnel are capable of performing while using the assigned tools, supplies, and test equipment.
- Includes inspecting, adjusting, lubricating, cleaning, making minor repairs, replacing parts in equipment, and servicing. The operator performs the maintenance.
- Includes unit replacement of aboveground joints of pipe, couplings, valves, and fittings; repair of small leaks using overleak clamps; and other repairs not involving construction or special handling equipment.
- Includes repair and maintenance of assemblies using authorized hand tools and small power tools. The equipment does not have to be removed from the area.

c. *Support Maintenance.* With this type of maintenance, the equipment is removed from the area, repaired, and then returned. Also, support maintenance requires special tools or equipment that the using organization is not authorized to use. Therefore, the using organization cannot perform this maintenance. Support maintenance includes overhauling the pump unit and repairing or reconstructing the pipeline. An example would be laying looped lines to bypass major breaks in the line.

6-2. Safety Precautions. Leaders must be aware of the hazards involved with the construction, operation, and repair of petroleum pipelines and must take measures to prevent accidents. The potential hazards must be identified and reduced before each operation is started. The following paragraphs discuss specific safety precautions pertinent to the construction and repair of pipelines and pumping stations.

a. *Fire and Explosion.* A constant fire and hazard explosion exists on a pipeline because of the fuels, Construction units must be aware of this during final testing of a newly constructed pipeline and during the repair of an existing pipeline. Units should use an explosimeter to determine how explosive and toxic an area is before entering it. When disconnecting a pipeline to replace damaged pipe or fittings or when a line break occurs, immediately shut down the line and close the closest block valves on each side of the break to capture as much of the fuel as possible before it becomes a fire hazard. Every opening could be a potential fire. Fire-fighting troops should accompany repair crews on major repair assignments. Observe the following precautions while repairing leaks or breaks in military pipelines:

- Keep all vehicles a safe distance from a leak.
- Approach the leak from the windward side.
- Do not approach a leak from a lower level; fuel vapors flow downhill.
- Know how to administer first aid for burns and how to give artificial respiration. Make sure you have adequate first-aid material, including burn ointment and blankets.
- Wear leakproof rubber or synthetic robber boots when standing in fuel.
- Use every precaution to prevent striking sparks when removing and replacing pipe fittings. Use sparkless brass hammers when replacing snap-joint couplings.
- Enforce and observe NO SMOKING rules.
- Never try to weld pipe holes; use clamps.
- Cover an area with petroleum fire-preventing foam even after repairing a leak or break and salvaging the fuel. The area may remain potentially dangerous for several days. Guards should be posted, and they should monitor the area for explosivity, as required.

b. *Projectiles.* A pipeline under pressure contains a large amount of potential energy. This energy is normally used to move fuel in the pipeline. If pipeline failure occurs, this energy is released suddenly and violently. Pipe sections and fittings can be thrown hundreds of yards. When repairing a coupled pipeline, repressurize and drain it before repairing it. Be very cautious when removing snap-joint couplings.

DANGER

Avoid working around pressurized pipeline. If you must work in such areas, try to remain shielded by large pieces of equipment or vehicles.

c. *Fuel Inhalation and Skin Contact.* Fuels, especially gasoline which contains lead and benzene, are potentiality dangerous to the health of personnel handling them. Inhaled vapors and prolonged skin contact may cause severe irritation. Persistent exposure to leaded gasoline can cause lead poisoning.

DANGER

An overdose of vapors may cause headaches, dizziness, nausia, unconsciousness, and death.

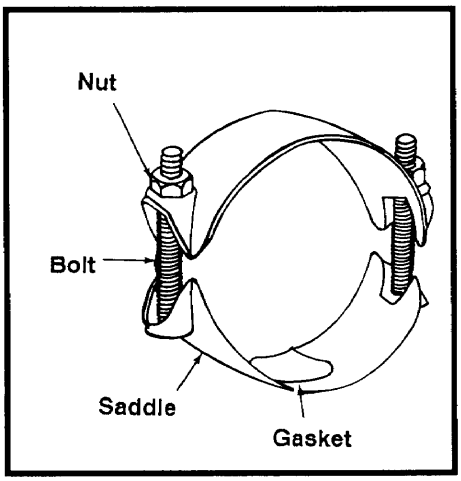


Figure 6-1. Pit-leak clamp

6-3. Coupled Pipeline.

a. *Temporary Repairs.* Repair small leaks in pipe sections and couplings, temporarily, by using clamps. The kind of clamp used depends on the kind of leak. It is not necessary to stop pumping operations while installing clamps. Replace the repaired pipe sections and couplings with new pipe and couplings as soon as possible.

(1) Pit-Leak Clamp. Small-caliber bullets can make holes in a pipeline. Rust can eat holes in the wall of a pipe. These small holes are called pit leaks; use a pit-leak clamp (Figure 6-1) to repair any leaks. If possible, drive small wooden pegs into the holes to stop the leaks until you install a clamp. To mount a pit-leak clamp--

(a) Place the saddle half of the clamp around the pipeline. The gasket should cover the small hole.

(b) Put the bolts in the saddle half of the clamp.

(c) Place the other half of the clamp around the pipeline and over the bolts in the saddle half of the clamp.

(d) Place the nuts on the bolts and tighten the nuts.

(2) Split-Leak Clamp. Flow and surge pressure in a pipeline can cause a section of pipeline to crack or split. Use a split-leak clamp to repair such a split (Figure 2-19, page 2-14). To mount a split-leak clamp--

(a) Cut gasket material large enough to fit the saddle of the split-leak clamp.

(b) Place the saddle half of the clamp around the pipeline. Cover the leak with the gasket and saddle.

(c) Place the clamp stirrups around the pipeline.

(d) Place the nuts on the ends of the stirrups and tighten the nuts.

(3) Overcoupling Leak Clamp. You can stop a leak at a split-ring, groove-type coupling by tightening the bolts on the coupling. Moving the pipe and coupling back and forth and up and down may reseal the gasket and stop the leak. If these actions do not stop the leak, use an overcoupling leak clamp to surround the faulty coupling (Figure 2-20, page 2-15). To install an overcoupling leak clamp--

(a) Take the vent plug out of the top of the overcoupling leak clamp. This allows the pressure and the fuel to escape while putting on the clamp.

(b) Remove the four large side bolts in the overcoupling leak clamp.

(c) Fit the two halves of the clamp and the two-part gaskets over and around the split-ring, groove-type coupling.

(d) Put the four large side bolts back in the clamp and tighten the nuts.

(e) Tighten the smaller packing bolts around each side of the leak clamp to form a seal between the two-part gaskets and the pipe.

(f) Put the vent plug back in the overcoupling leak clamp. Tighten the vent plug.

b. *Permanent Repairs.* To make permanent repairs on coupled pipelines, break the line and replace the faulty coupling, pipe, or fitting. Before breaking a pipeline, drain its contents and release the pressure. Fuel vapors in the area of the break left in the line and that have collected in low areas could cause a fire, if ignited. To prevent ignition--

- Keep vehicles away from the break.
- Remove anything that could cause a spark.
- Cover any fuel that spills on the ground with fire-retarding foam.

WARNING

When removing snap-joint couplings on a line under pressure, use extreme caution to avoid personal injury.

(1) Coupling Replacement. Always make sure that fire-fighting equipment is nearby when replacing a coupling. To replace a faulty coupling--

(a) Stop pumping operations that affect the area you are to repair.

(b) Close the closest gate valve on each side of the area you are to repair.

(c) Drain the line and release the pressure.

(d) Remove the overcoupling leak clamp by removing the four large side bolts if a temporary repair was made. Catch spilled fuel in a container.

(e) Remove the split-ring coupling and gasket. Drain any fuel from the repair section into drums or tank vehicles. (One mile of 6-inch pipeline holds 210 barrels (8,400 gallons) of fuel.)

(f) Inspect the coupling and gasket to determine the cause of the leak. Replace the defected parts.

(g) Reinstall the coupling. You may need come-alongs to drawl the pipe ends together for coupling procedure.

(h) Open the gate valves slowly to put pressure back in the pipeline.

(i) Start pumping.

(j) Remove air from the repaired section by opening the vent valves in the section. If possible, send a scraper through the repaired section to evacuate the air.

(k) Bring the repaired section up to test pressure and check the repaired coupling for leaks.

(2) Pipe Replacement. To repair a section of coupled pipeline, replace the bad section of pipe with a new section. Always make sure that fire-fighting equipment is nearby when replacing a pipe. To replace a pipe--

(a) Stop pumping operations that affect the area you are to repair.

(b) Close the closest gate valve on each side of the area you are to repair.

(c) Drain the line and release the pressure.

(d) Remove the coupling and gasket. Drain any fuel from the repair section into drums or tank vehicles.

(e) Reinstall a new pipe section. Inspect the used gaskets before reinstalling them. You may need come-alongs to draw the pipe ends together for coupling procedures.

(f) Open the gate valves slowly to put pressure back in the pipeline.

(g) Start pumping.

(h) Remove air from the repaired section by opening the vent valves in the section. If possible, send a scraper through the repaired section to evacuate the air.

(i) Bring the repaired section up to test pressure and check the replaced pipe section for leaks.

Chapter Seven. Bulk-Fuel Storage Facilities

7-1. Tactical Petroleum Terminal. The TPT is the Army's bulk-fuel storage facility. It is a fuel-handling system designed to receive, store, and issue bulk petroleum fuels, specifically diesel and jet fuels, The TPT serves as a base terminal in an undeveloped theater and can be used in the developed theater to supplement existing facilities that are inadequate or damaged. The TPT can store up to 1,080,000 gallons of fuel in each of its three fuel units. Each fuel unit can be dedicated to a specific type of fuel. The six optional 50,000-gallon tanks increase the system's capacity. Fuels can be received from a pipeline or from tanker vehicles. The TPT can dispense the fuel directly to user vehicles, but it usually limits issue to bulk-fuel transport vehicles. The TPT can also return fuel to the pipeline for distribution downstream. The system can receive fuel at a rate up to 800 GPM. Each fuel unit can issue fuel at rates up to 600 GPM. Figure 7-1 (page 7-2) shows a typical TPT layout, including separate dispensing areas for different type fuels. The major components that make up a TPT are--

- Eighteen 2 10,000-gallon fabric tanks.
- Six 50,000-gallon fabric tanks.
- Fifteen 600-GPM pumps.
- One 350-GPM pump.

a. *Responsibilities.* The theater support command is responsible for specifying the capacities and general locations of bulk-storage facilities. The petroleum group within the support command is tasked to develop, design, and construct the petroleum distribution and storage facilities based on the operational plan of the theater commander. The quartermaster petroleum/lubricant (P/L) company is responsible for installing fabric tanks. Fabric tank farms require a large, flat area for construction. Engineers are responsible for the earthwork at the TPT site, which includes constructing tank pads, earth berms, and roadways. Tank-farm locations must be cleared and leveled, and all tanks should have a berm around them to protect them from enemy fire and to retain the contents if the tanks rupture.

b. *Terminals.*

(1) Base Terminals. Base terminals serve ports of entry and provide initial storage of petroleum products in a TO. These terminals are in rear areas, at or near ports of entry, or at other tanker loading and unloading points. A TO may have more than one base terminal. The base terminal is generally the largest bulk-fuel installation of the pipeline system. In an undeveloped theater, the TPT may serve as a base terminal. The base terminal should be large enough to--

- Provide storage for unloading, within 24 hours, the full cargo of the largest tanker that may be scheduled.
- Provide storage for reserve supplies of each fuel to be carried through the pipeline or dispensing lines fed by the tank farm.

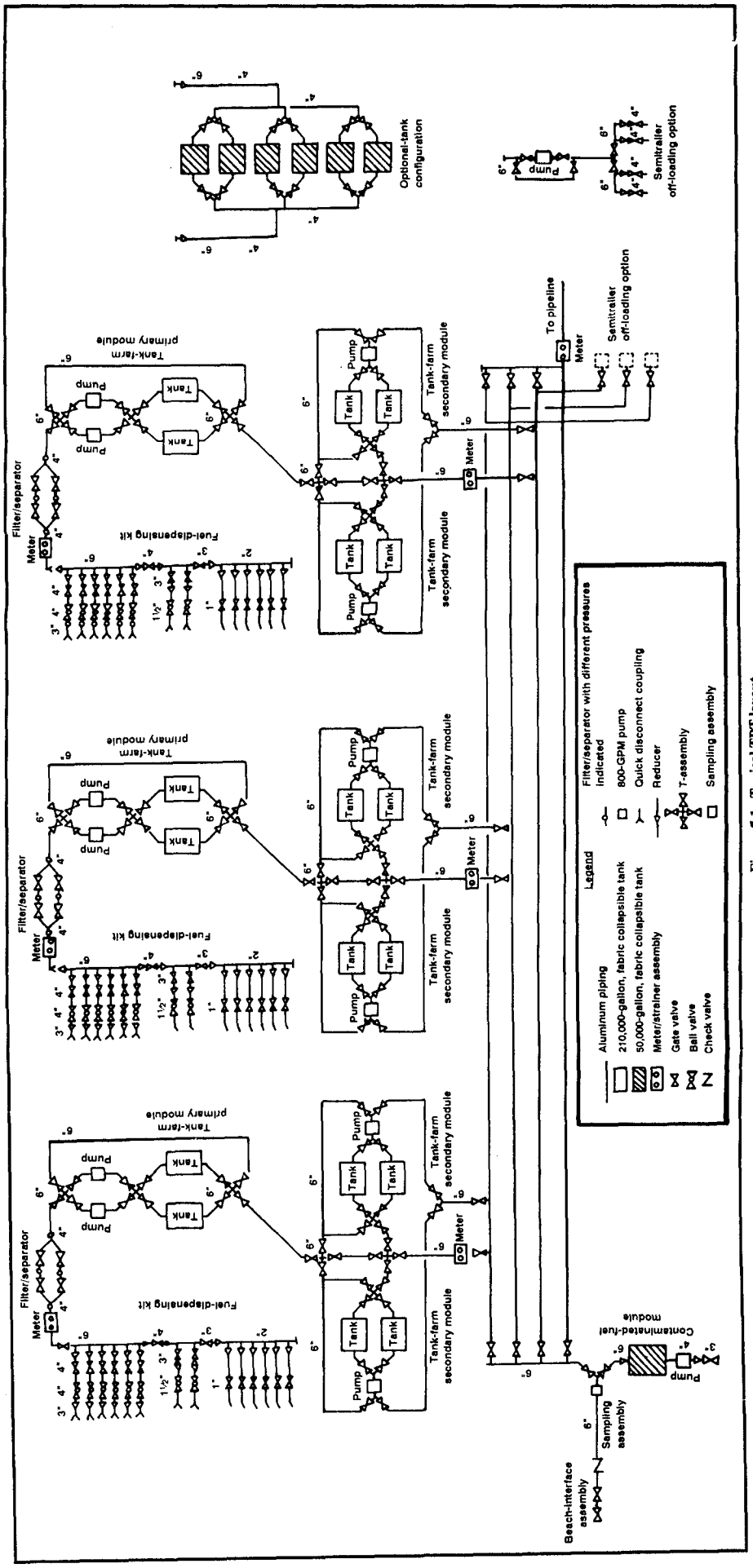


Figure 7-1. Typical TPT layout

- Have enough reserve operating capacity so that products can be received and issued at the same time.
- Have enough capacity to allow fuel received from a tanker to settle at least 24 hours before it is pumped through the pipeline.

(2) Intermediate Terminals. These terminals serve as reserve-storage and dispensing installations. The location and size of the terminals depend on the capacity of the pipeline system, the nature of the pumping operation, and the tactical situation. There should be enough storage capacity to receive and issue fuel at the same time. Intermediate terminals will be located, at a minimum, after every fifth pumping station. This will allow the quartermaster operating unit to coordinate pumping-station activities.

(3) Head Terminals. These terminals may be located in the main supply areas of an independent corps. Tanks at a head terminal may be either fixed or fabric, depending on the pipe head location, the needs of the troops, and the tactical situation.

(a) Fixed. The pipe head is usually a fixed installation that services a group of airfields in the TO's rear area or Class III supply points only. A fixed installation may include head terminals or branch lines, storage tanks, tank-truck loading facilities, tank-car loading and unloading facilities, and can-and-drum filling stations.

(b) Portable. The pipe head is portable when it is in the corps' supply area because it may have to move with the forward supply points every few days. As a rule, portable tank-farm facilities are used for storage. Forward petroleum supply facilities may be supplied by hose lines from this portable storage. Tanker vehicles may be used with the portable tanks to increase storage.

c. *Regulating Facilities.* Any excess tanks at a terminal may be used as a regulating facility. The extra tanks are used to store reserve fuel. When a break occurs in a line, pumping is stopped in the damaged section. The fuel at the regulating facility downstream from the break is pumped instead. This confines breaks to one point in the pipeline and allows pumping to continue during repairs. Regulating facilities should have the capacity to store enough fuel to continue pumping operations for six hours.

d. *Tank Farms.* A tank farm is the main component of a pipeline terminal. It is a group of collapsible fabric tanks connected by pipelines. The pipelines in the tank farm are joined so that products can be moved into, out of, and between storage tanks. Military tank farms are complete installations made up of various facilities, operation buildings, and security fences. A tank-farm size depends on the needs at the particular terminal. Standard tank farms listed in AFCS are in the following barrel capacities: 50,000; 100,000; 150,000; 200,000; and 250,000.

(1) Complexes. If more than a 250,000-bbl storage capacity is needed at a single terminal, two or more tank farms are installed to provide enough storage. These tank farms are connected by a central switching manifold. Each group of tank farms is a tank-farm complex. The tank farms in each complex should be spaced at least 4 miles apart. Each tank farm is usually supplied by two branch lines joined to two incoming trunk pipeline. Booster stations are placed in each branch line to provide the needed line pressures for proper flow to the switching manifold. Standard tank-farm complexes are normally in barrel capacities of 400,000; 600,000; 800,000; and 1,000,000.

NOTE: For clarity, further tank capacities will be in gallons only. To convert barrels to gallons, multiply the gallon amount by 42 as there are 42 gallons of fuel to one barrel.

(2) Portable Facilities. Standard, portable tank farms are installed where portable storage is needed. Portable tank farms have 10,000-; 20,000-; 50,000-; or 210,000-gallon collapsible tanks and the equipment needed to connect them to the main line. The capacity of the tank farm depends on the size and number of collapsible tanks.

(3) Collapsible Fabric Tanks. These tanks come in 3,000-; 10,000-; 20,000-; 50,000-; and 210,000-gallon capacities. The tanks require large, flat areas that engineers construct. Eighteen 210,000-gallon fabric tanks makeup a complete TPT. Because they are easy to install, fabric tanks have made steel tanks obsolete.

(a) 3,000-gallon tank (Figure 7-2). The primary use of this tank is to provide fuel for mainline pumping-station operations. The tank is made of coated nylon. It has a 3-inch fill-and-discharge assembly. The tank is about 13 feet square and 6 feet high.

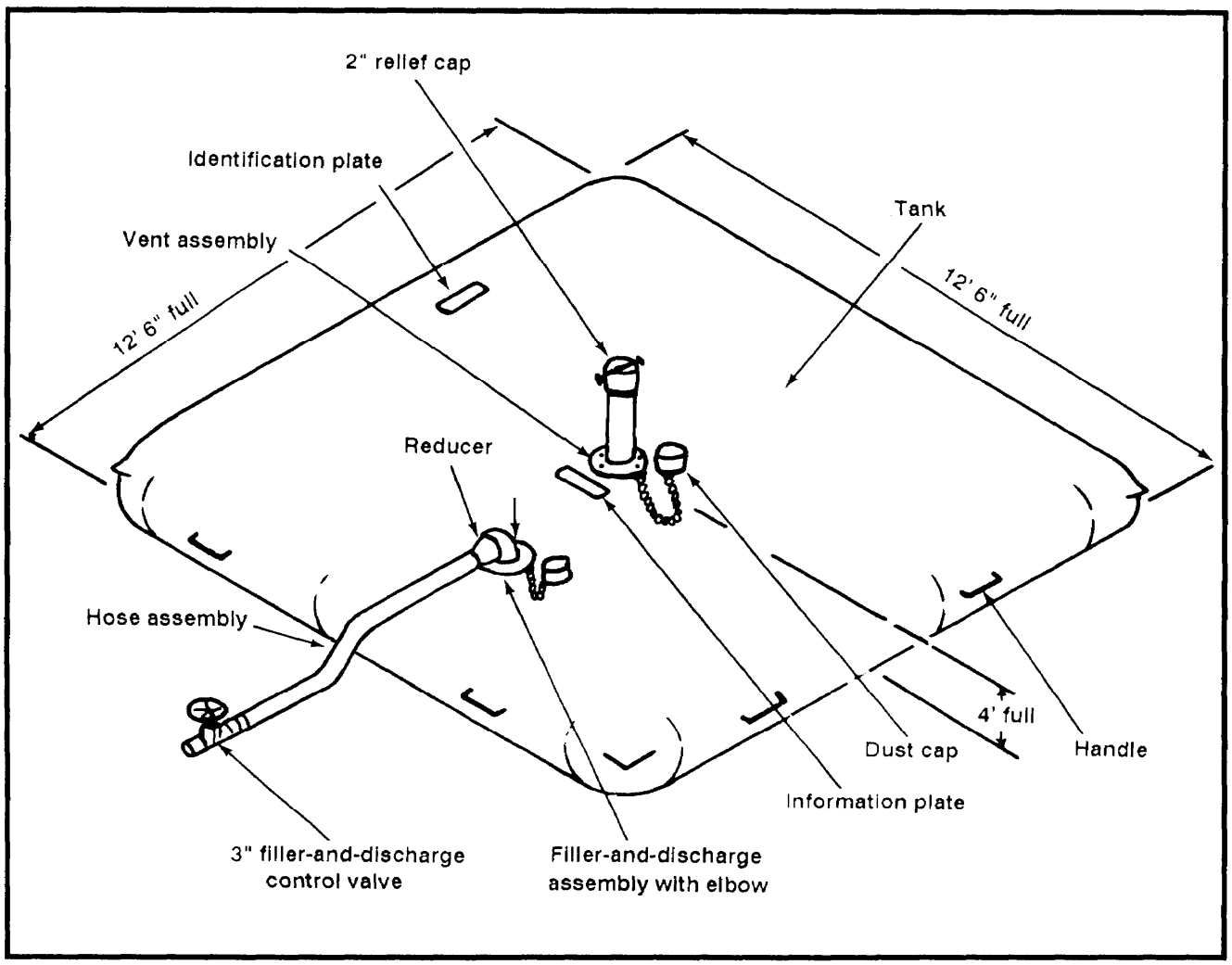


Figure 7-2. Collapsible fabric tank (3,000-gallon)

(b) 10,000-gallon tank (Figure 7-3). Two types of this tank exist in the Army inventory: the square and the rectangular models. They are used for temporary storage and for dispensing tanks at portable, pipe-head tank farms. These tanks may be used in the fuel-system supply point. Both models are made of coated nylon. They have positioning handles, a fill-and-discharge assembly and fittings, a pressure-relief assembly, and a drain assembly. Each tank has a 4-inch manifold assembly with fittings and a repair kit. The square tank is about 20 feet square and 4 feet high. The rectangular tank is about 40 by 11 feet and 4 feet high.

(c) 20,000-gallon tank. This tank is primarily used in the fuel-system supply point. The tank is issued as a single item of equipment for additional bulk storage. It is made of elastomeric-coated nylon and has 12 carrying handles, two 4-inch filler/discharge assemblies with access doors, a vent-fitting assembly, and a drain-fitting assembly. When filled, the tank is about 28 by 24 feet and 5 feet high.

(d) 50,000-gallon tank. This tank is used for initial storage at beachheads and for storage along trunk hose-line and pipeline systems. It may be used for storage at fixed supply installations and airfields until permanent tanks can be built. This tank is made of lightweight, single-ply, rubber-coated fabric. Each tank has two 4-inch combination inlet and outlet connections, a 2-inch combination overflow and vent fitting, and a 1/2-inch drain plug. Tank accessories include a manifold assembly with half valves and couplings and a clamp kit, *D* -rings, and gaskets. The tank is about 65 by 25 feet and 5 1/2 feet high when filled.

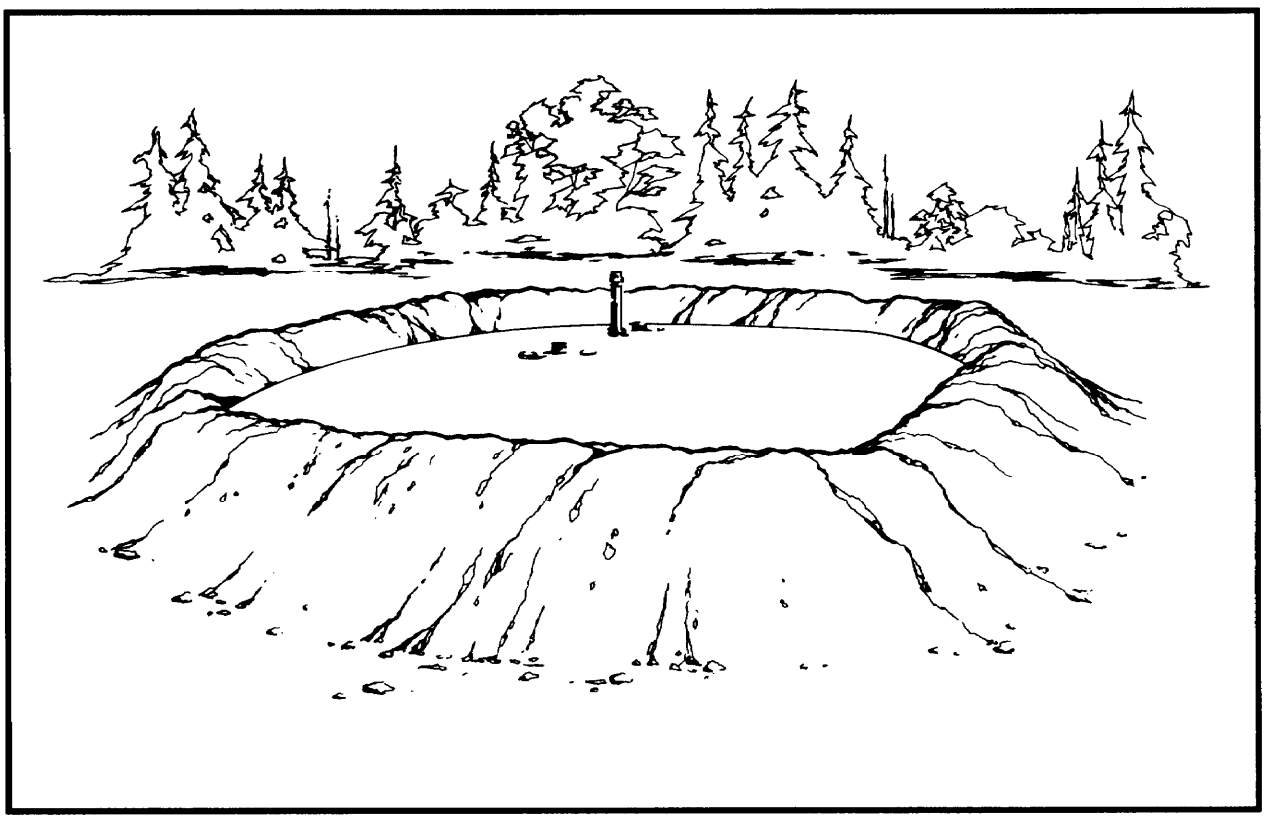


Figure 7-3. 10,000-gallon storage tank

(e) 210,000-gallon tank. This tank, also called a bulk-fuel tank assembly (BFTA), is primarily used for initial storage at beachheads as an integral part of the TPT tank-farm complex. Other than size, the 210,000-gallon tank resembles the 50,000-gallon tank in appearance. It has two 6-inch combination inlet and outlet connections and a vent tube on top. When filled, the tank is 70 feet square and 8 feet high.

e. Site Criteria. Tank farms must be located in the area that they are to supply. The general location is designated by the petroleum group, which is responsible for the design, construction, and operation of the distribution system. Site selection is relative to the location of Class III supply points and transportation routes, whether by pipeline, tanker truck, barge, or rail tank car. The specific location may have to be modified due to site constructability.

The engineer unit tasked to the construction site must work closely with the petroleum group in exact layout and placement of the tank farm. The selected sites should be in noncongested areas where other facilities do not interfere and where sabotage and sneak raids are relatively easy to defend against. Tank farms should never be located in drainage areas above critical installations. Site tank farms so that a tank-farm fire will not spread to other supply areas or installation areas. The tank-farm site should have as many of the following features as possible:

- Adequate road and/or rail facilities for transporting pipeline and tank-farm equipment and supplies.
- An area large enough for proper tank dispersion and expansion of the tank farm. This is a major factor when collapsible fabric tanks are used because of the large area required.
- Absence of distinctive landmarks or terrain features that could aid enemy aircraft in locating and identifying the site or could be used to adjust artillery fire.
- Terrain that allows tanks or groups of tanks to be separated b y terrain masses to minimize damage due to the blast effects of atomic weapons or other large effect munitions.

(1) Hydraulic Design. Try to choose a site that gives the minimum required suction pressure by gravity flow from the outlet of the lowest tank to the intake of the pipeline pumping station that is to pump from the tank farm. The pressure should be at least 20 psi.

(2) Topographic Features. The best sites are on flat ground in sloping terrain with adequate natural cover and concealment. This allows for gravity flow to the first pumping station and isolates tanks for damage protection. Beachhead sites may be located in sandy seashore areas up from the beachline and on old harbor terraces. Desirable inland sites may be situated on bench terraces along valley borders or at points on a terrace where a small stream or gully cuts through.

(3) Soil Conditions. The site should have adequate drainage. Preferably, the water table should be more than 6 feet below the surface. Avoid marshlands, riverbanks, or bottomland subject to flooding and other sites with poor or undependable drainage.

f. *Flexible Hose Lines.* These hose lines are available in various lengths, diameters, and strengths, depending on their use. Low-pressure hoses are used for moving fuel inside petroleum-storage facilities. They are also used during the assault phase of a military operation when the advancing elements push forward more rapidly than metal pipelines can be constructed.

High-pressure hoses, as part of the OPDS, move fuel from ship to shore, replacing the need to weld and install an underwater pipeline.

g. *Hose Connection Devices.*

(1) 6-Inch, Cam-Lock, Male-by-Double-Grooved Adapter. This adapter (Figure 7-4) is used in the tank-farm assembly. It is connected to the hose that goes to the elbow coupler on the tank inlet.

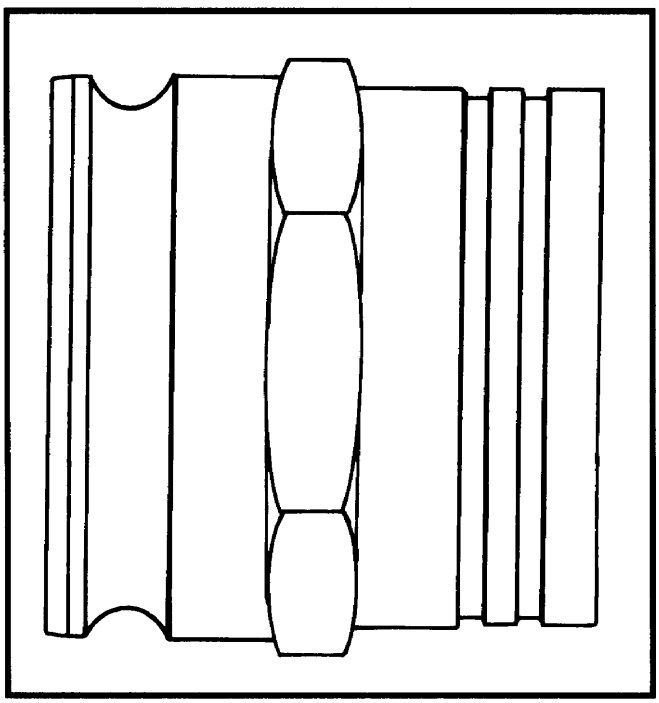


Figure 7-4. 6-inch, cam-lock, male-by-double-grooved adapter

(2) 6-Inch, Cam-Lock, Female-by-Double-Grooved Adapter. This adapter (Figure 7-5) is used in the tank-farm assembly. It is connected to the cam-lock gate valve on the discharge line leading to the 210,000-gallon, collapsible, fabric tank.

(3) 6-Inch, Bolt-On-Type, Hose-to-Cam-Lock, Male and Female Adapters. This device is installed on the ends of the 6-inch hose-and-reel kit. It is available in male and female configurations.

(4) Cam Lock. This is a quick connect fitting found on valves and hoses in the TPT and low-pressure areas of pumping stations. The cam lock is a low-pressure connection with a MAWP of 150 psi.

h. *4-Inch, Single-Stage, 350-GPM Pump.* This unit (Figure 7-6, page 7-8) consists of a 3-cylinder, 4-stroke, diesel-engine power unit and a single-stage centrifugal pump. This pumping unit is designed for use with the contaminated-fuel system for loading out or transferring contaminated fuel, but it can be put in general utility service as necessary. Operating at 2,300 RPM, the unit will pump 350 GPM with 275 feet of head.

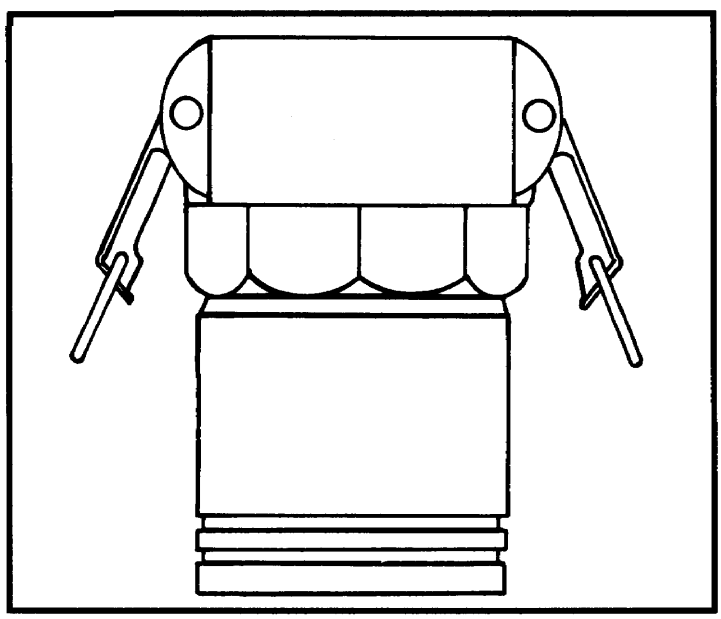


Figure 7-5. 6-inch, cam-lock, female-by-double-grooved adapter

i. *Filter Separator.* The filter separator is frame-mounted in the pipeline manifold between the pump and the loading rack of all dispensing facilities. It is used to remove entrained solids and to free water from the fuel before the user

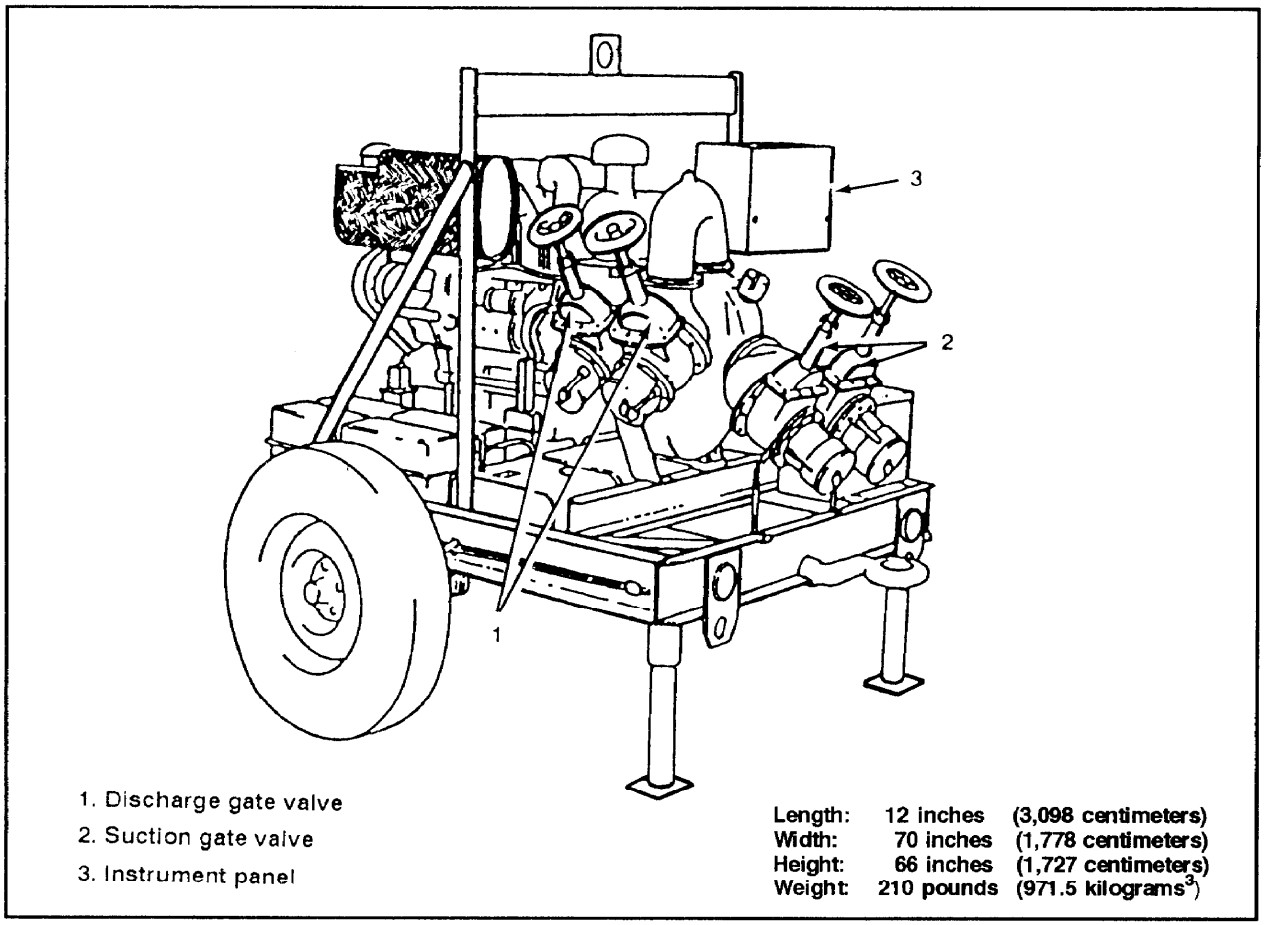


Figure 7-6. 4-inch, single-stage pump (350-GPM)

receives it. Free water may be present in the fuel in two forms, in a fine dispersion or in large *slug* quantities. The filter separator passes the contaminated fuel through a series of filter/coalesce elements. These elements may be constructed from various combinations of fiberglass mat or cloth; paper and nylon, dacron, cotton, or wool cloth, as long as the elements meet the performance specifications outlined in MIL-F-52308. The entrained solids are caught and held by the fibrous material, and the water is coalesced into large drops. Because water and fuel have different specific gravities, the waterdrops fall to the bottom of the filter/separator vessel and forma pool. The 15-, 50-, 100-, and 350-GPM filter separators are equipped with a water-level sight glass and a manually operated valve to drain water from the sump.

The pump unit is mounted to the front portion of the skid frame and is attached to the engine bell-housing and flywheel. The suction and discharge assemblies are mounted to the pump body. The unit is a single-stage, centrifugal pump that is self-priming after an initial filling. The pump body and volute are a one-piece aluminum casting with a 6-inch suction port at the front of the pump body and a 6-inch discharge flange at the top of the pump body.

The bronze alloy impeller is enclosed in the close-fitting volute of the pump body. Replaceable wear plates in the pump body take most of the internal pump wear. The impeller is secured to the end of the impeller shaft. The impeller shaft, coupling assembly, shaft seal, and bearings that support

the impeller shaft are contained in the bearing housing. The pump body is fitted with a 1 l/2-inch priming port with a quick-disconnect, cam-locking, male coupling. The coupling has a cam-locking dust cover secured to the pump body by a short length of chain.

7-2. TPT Site Selection and Earthwork.

a. *Site Selection.* The P/L company is responsible for TPT site selection. When choosing an exact site location, a construction engineer should be present to evaluate the constructability of the site. The P/L company should consider the following factors in site selection:

(1) Area. The site must be large enough (about 40 acres) to contain the required equipment and roadways. Flexibility is important when setting up the area.

(2) Terrain. The site selected should be reasonably level and well-drained, especially where equipment is loaded, unloaded, and stored. The P/L company should consider the following when selecting the terrain:

- Low, swampy areas. Try to avoid such areas.
- Large rocks and trees. The area should have as few of these as possible.
- Earth-moving equipment. Determine how much is needed to accomplish the mission.

(3) Road Access. If possible, the site should be located relatively close to existing road systems that can carry the traffic involved. The road system must be accessible or a new road will have to be built to connect the existing road systems.

(4) Water Availability. If possible, water should be available at the site. If none is available, it should be brought in. Water availability is a safety factor. Water must be available for charging the aqueous film-forming foam (AFFF) on a wheel-mounted fire extinguisher, for general fire protection, and for personnel safety.

(5) Local Population. The site should be well away from local population concentrations.

(6) Plot Plan and Site Investigation. After the P/L company selects the site, they should--

- Make a preliminary plot plan showing all the major equipment and system locations, including tanks, pumps, fuel-dispensing areas, tanker-truck receipt areas, access roads, and pipeline route into and out of the site.
- Make primary cuts and fills so details of the site's characteristics can be seen before starting earthwork on tank sites, berms, and roadways.
- Review the preliminary plot plan and correct it as needed.
- Make a final plot plan indicating permanent equipment locations.
- Construct final roadwork and tank pad and berms, based on the final plot plan.

b. *Earthwork.* Earthwork requirements at TPT locations are tank berms and pads, roads, and culverts. This work requires the support of an engineer unit, normally a combat heavy engineer battalion. Earth berms are constructed around POL tanks to protect them from enemy fire and to retain the contents should the tanks rupture or catch on fire. The size or height of the berms should

be such that the volume of liquid in the tanks can be contained within the berms should a rupture occur. Once a site is selected, do the following for a fabric tank farm:

- Clear the site and grade about a 1 percent slope towards the tank drain assembly. Remove any sharp objects that could puncture the fabric tank.
- Construct berms around single or paired tanks from the surrounding area (see Figure 7-7 and Figure 7-8, page 7-12).
- Place a berm basin drain at the lowest end of the tank pad. The drain is a pipe (2-inch diameter minimum) with a gate valve. Place this pipe under the berm during construction.
- Add 1 foot of height to the berm, as a safety factor. The berm should extend above the top of the tanks and be at least 4 feet wide at the crown. The walkway between a tank and berm should only be wide enough to allow for maintenance.

The type of earthwork construction depends on the site conditions and available materials. There are three general forms of construction (see Figure 7-9, page 7-13). A berm entirely above ground allows for rainwater drainage but is the least desirable because it must be made of fill. A maximum amount of earth must be hauled to the site, increasing time and expense. When possible, you can minimize the time needed for moving soil by equating the volume of the cut with the volume of fall, as closely as possible.

c. General Site Preparation. Site selection and preparation and earthwork must be based on the plot plan that the terminal-operating unit prepare. Again, flexibility is important between using the plot plan and preparing the site. Consider using the following procedures:

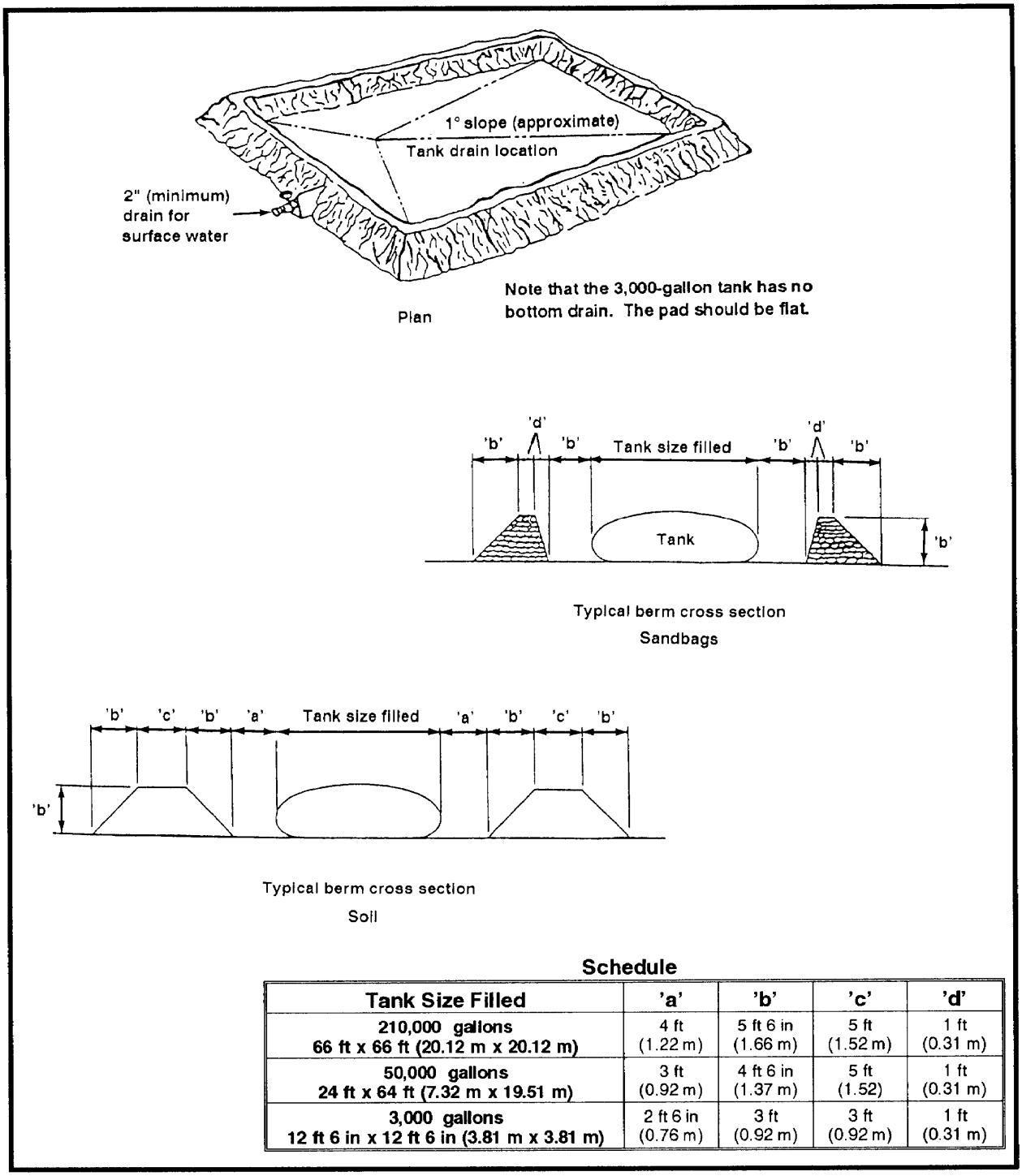
- Base site preparation work on a grading plan that minimizes cut and fill operations even if the plan is roughly prepared in the field.
- Base the plan on actual on-site elevations and survey, obstructions, and knowledge of the types of soils that appear to be present.

(1) Cut an Access Road. Cut an access road, unless one already exists.

(2) Stake out the Area. Stake out the area that must be cleared, marking areas where the major components will be located. Cut, grub out, doze, or blast out major obstructions such as trees, bushes, large rocks and boulders, and buildings.

(3) Clear the Area. Clear and grade the areas where fuel tanks will be located, transfer systems installed, roadways built, and loading and unloading facilities installed. You do not have to clear and grade the entire area required for a TPT. Make sure you allow for good drainage from the site.

(4) Cut and Fill. When possible, plan and execute cuts and fills so that the volume of cut soils roughly equals the amount of fill needed for low spots, tank berms, and roadways. If the area is fairly flat and requires only minimal grading, get the materials for roadways and tank berms from a borrow pit near the site. You can convert this pit to a reserve water-storage basin, if desired. When you prepare the grading plan and execute the cut and fill, try to set the major equipment, especially the 210,000-gallon tanks, on virgin or cut soils rather than on fill. If you cannot, compact the fill while setting the equipment. When you need large amounts of fill, the slopes must be such as to



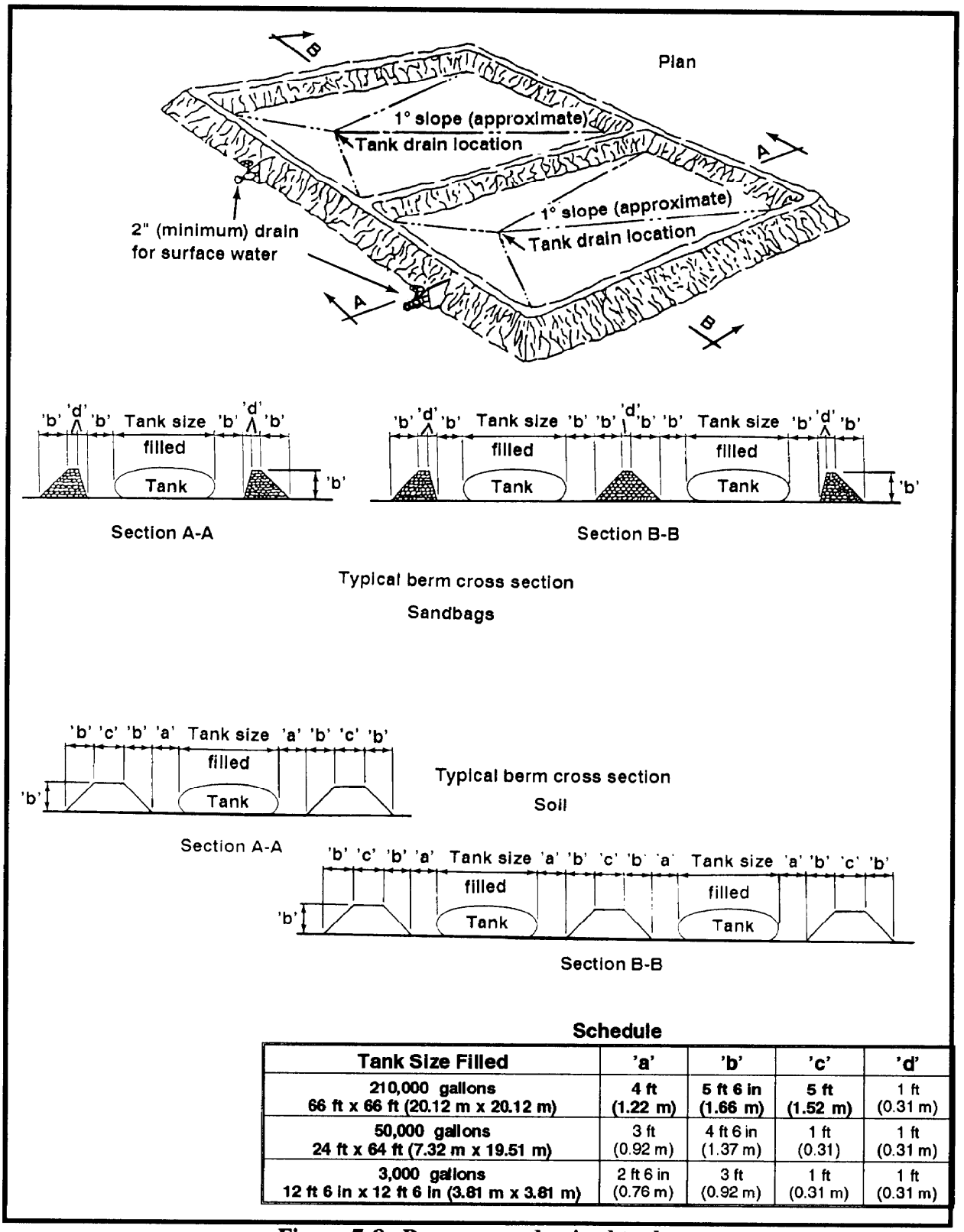
Schedule

Tank Size Filled	'a'	'b'	'c'	'd'
210,000 gallons 66 ft x 66 ft (20.12 m x 20.12 m)	4 ft (1.22 m)	5 ft 6 in (1.66 m)	5 ft (1.52 m)	1 ft (0.31 m)
50,000 gallons 24 ft x 64 ft (7.32 m x 19.51 m)	3 ft (0.92 m)	4 ft 6 in (1.37 m)	5 ft (1.52)	1 ft (0.31 m)
3,000 gallons 12 ft 6 in x 12 ft 6 in (3.81 m x 3.81 m)	2 ft 6 in (0.76 m)	3 ft (0.92 m)	3 ft (0.92 m)	1 ft (0.31 m)

Figure 7-7. Berm around single tank

prevent slides and minimize erosion. As a general rule, slopes should be no greater than 2:1 (about 25 degrees) in sandy or loamy soils.

(5) Construct Roadways. Roadways must be fully compacted, have good drainage, and have at least a surface of gravel or crushed rock, if possible. Each side of the road should have an adequate



Schedule

Tank Size Filled	'a'	'b'	'c'	'd'
210,000 gallons 66 ft x 66 ft (20.12 m x 20.12 m)	**4 ft (1.22 m)**	**5 ft 6 in (1.66 m)**	**5 ft (1.52 m)**	1 ft (0.31 m)
50,000 gallons 24 ft x 64 ft (7.32 m x 19.51 m)	3 ft (0.92 m)	4 ft 6 in (1.37 m)	1 ft (0.31)	1 ft (0.31 m)
3,000 gallons 12 ft 6 in x 12 ft 6 in (3.81 m x 3.81 m)	2 ft 6 in (0.76 m)	3 ft (0.92 m)	1 ft (0.31 m)	1 ft (0.31 m)

Figure 7-8. Berm around paired tanks

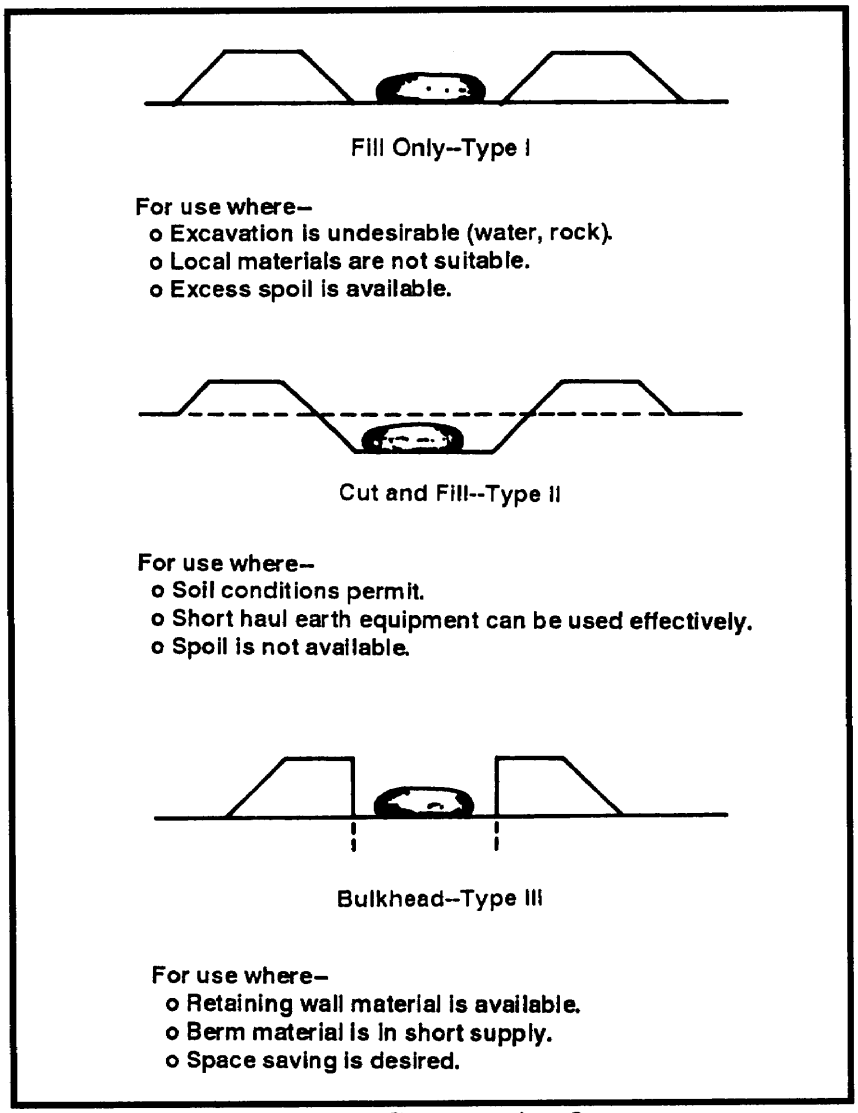


Figure 7-9. Construction forms

swale or ditch for good drainage. Place drainage culverts where necessary. The road, swale, ditch, and drain culvert requirements will vary with site conditions and anticipated rainfall. Construct roadways for ready access to all areas for installation, operation, fuel loading and unloading, and fire fighting.

d. *Tank Pad and Berm Construction.* You must construct these items properly. Doing so could protect tanks from spills or fires resulting from spills. Tank pads must be free of rocks, sticks, and sharp objects to prevent tank damage.

(1) Tank Pads. The preferred materials for construction are loamy or clay soil containing some sand so that you can grade a smooth area that will hold its shape. The longest slope should be about 10 degrees from horizontal. Shorter slopes will be greater. The low point should be where the tank drain will be after the tank is unrolled, to allow maximum pumping out and drainage through the drain line. The base of the tank-pad area must be virgin or cut soil or be well compacted. To avoid damaging the tank bottom, remove sticks, stones, or sharp objects before installing the tank. You can excavate, by hand, a small ditch and basin for the tank drain line and drain valve as the tank is unrolled.

(2) Berms. You can construct berms before, during, or after tank-pad construction, depending on job conditions. Make sure the tank pad is clear of any rocks or clumps that could roll during berm construction. Try to finish the tank-pad rough grading before constructing the berm. Finish tank-pad grading after constructing the berm. The preferred materials for construction are soils with a fairly high clay content to hold shape and provide sealing. Compact the berm as you construct it. (An alternative to graded berms are sandbag berms.)

(3) Drainage. If you install a berm drain, lay it in a hand-cut trough after placing the first layer of berm but before placing the second layer. Be careful so that the equipment used to construct the berm does not damage the drain. To avoid this problem, do not install the valve until you complete the berm, giving the berm drain pipe plenty of cover. When installing the drain valve, make sure that it is in the closed position. Open the valve only to drain the basin, when necessary.

(4) Liner. If the installation authority decides to install construction-grade, polyethylene sealing sheets, install them after completing the pad and berm. Spread a light layer of soil (without rocks) to protect the sheeting and to hold it in place. Do this after you seal the sheeting joints.

e. *Pads for Other Equipment.* Try to set all operating equipment on virgin or cut soils rather than fill. If you must use fill, it must be well compacted. This is particularly important for the pumps and floodlight sets. If available, try to cover the areas on which you place equipment with a 4- to 6-inch layer of coarse gravel or crushed rock. Extend the gravel or crushed rock out and around the equipment for several feet. This will provide a high, dry area from which to operate and maintain the equipment. Placing coarse gravel or crushed rock at and around often-operated valve stations is a good practice.

7-3. TPT Layouts. Space is a key factor in the site layout of a TPT using fabric tanks. Dispersion is essential to limit damage from air attacks, to make the best use of natural cover (thereby simplifying concealment), and to reduce fire hazards intrinsic to storage of flammable products. The petroleum group and their subordinate units are responsible for the exact layout of a tank farm. Close coordination between the engineer support unit and the quartermaster unit is essential.

Tank spacing in a TPT is a trade off between safety and efficiency in operation. As a general rule, a TPT should be arranged for maximum spacing between tank-farm modules and fuel units based on the operating requirements and the available hose lines. This will provide for the highest level of safety for the equipment and the operating personnel without adversely affecting operating efficiency. The minimum recommended spacing between 210,000-gallon tanks with berms is 50 feet. The layout should provide rapid access to all areas. Site characteristics include distances to pipeline pumping stations and manifolds and the length of tank-farm pipe connections. Spacing should not require excessive pumps and lengths of pipe or an excessively large defense perimeter.

Try to limit and control access in and out of a TPT. A road capable of supporting two-way tanker-truck traffic should run along the perimeter of the TPT site, giving access to each fuel-unit dispensing assembly. In a TPT, use secondary roads to transport the material-handling equipment used in the operation and maintenance of the area and the fire-suppression equipment. You must be able to approach tanks from two directions to prevent a burning tank from blocking the road to other tanks. Place all hose lines that cross roadways within a TPT in culverts below ground level.

a.. *General Layout.* The layout requirements for a TPT must be flexible to fit the particular site and service. The objective in any equipment arrangement is to provide for efficiency and safety in operations. Specific area-service requirements may affect layout and spacing. This manual outlines several alternatives and criteria in TPT layout. Layout modification will depend on need.

(1) Area. Figure 7-10 shows a typical wide-spaced TPT layout. It has been arranged to make full use of the transfer hose lines between fuel modules. The layout assumes that adequately sized

property is available. The equipment is wide-spaced for security reasons. Terrain or operational situations could account for different appearances in wide-space layouts. The installing and operating authority makes the final determination of TPT layout. In a relatively secure area or when property availability is limited, the layout arrangement should be a close-spaced TPT layout (Figure 7-11, page 7-16).

(2) Access. Road access should always be considered when planning a TPT site. However, the site should have a limited number of entry points. Each entry point should have a control or checkpoint to monitor and route traffic in and out of the area. A road capable of supporting two-way tanker-truck traffic should run along the perimeter of the TPT site, giving access to each fuel unit's fuel-dispensing assembly. In the fuel-dispensing assembly areas, the roadway should be at least 40 feet wide. Through traffic should be routed away from the fuel-dispensing area. Fuel-handling areas are necessary for the contaminated-fuel module and the tanker-truck receipt manifolds.

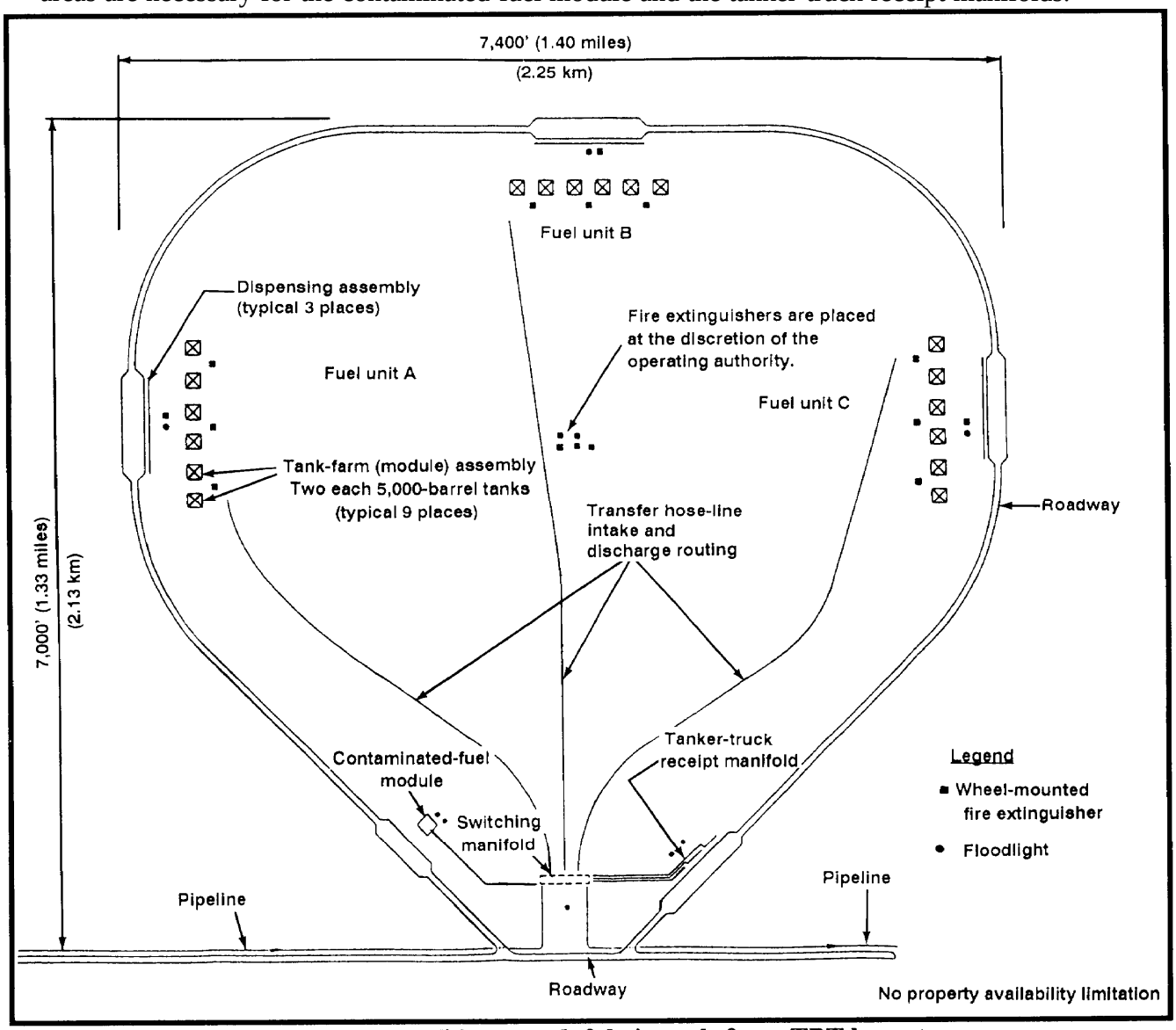


Figure 7-10. Wide-spaced, fabric tank-farm TPT layout

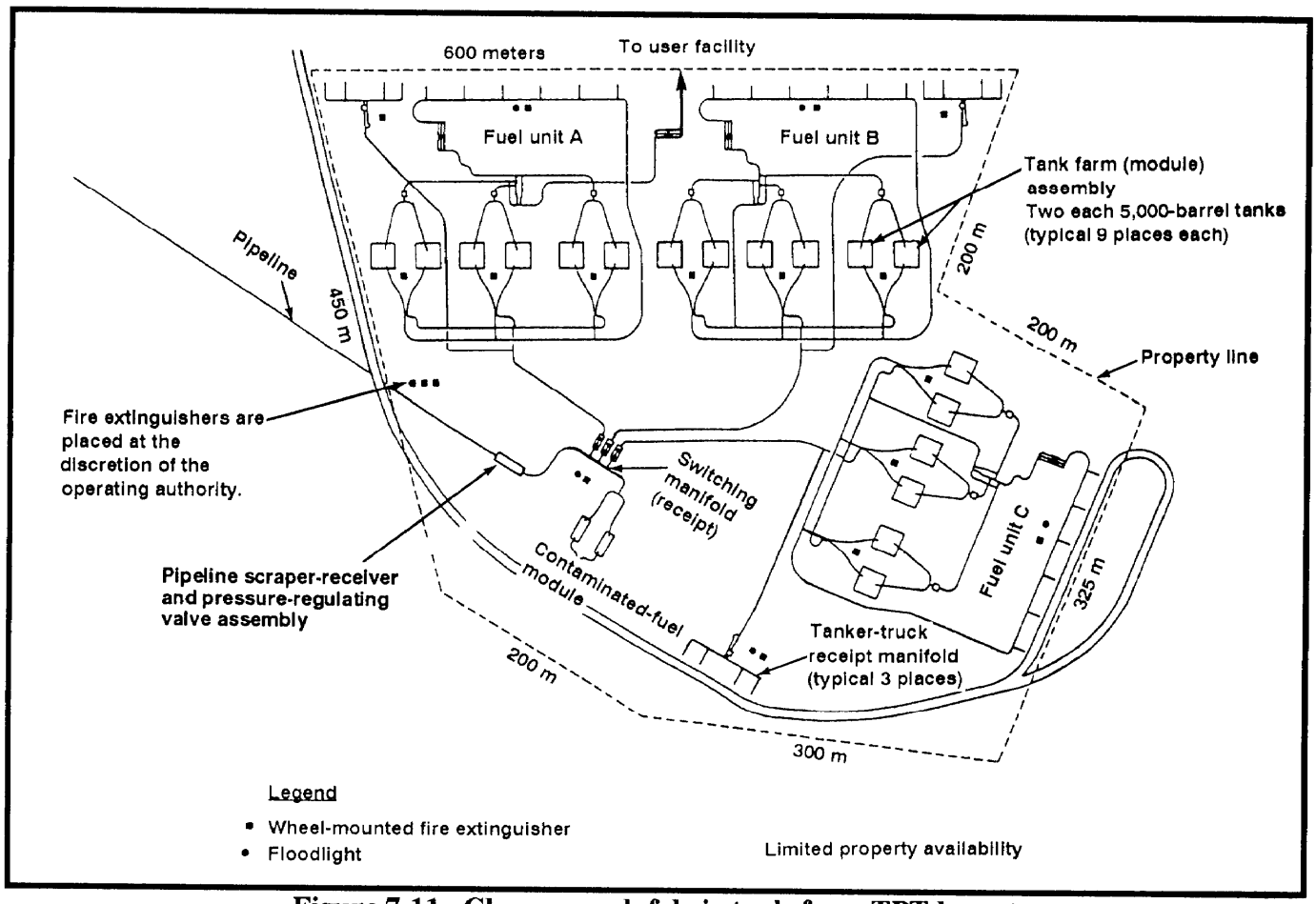


Figure 7-11. Close-spaced, fabric tank-farm TPT layout

Although not shown on the layout, secondary roadways should be in the TPT to allow for movement of material-handling equipment, pumps, and fire-suppression equipment and for maintenance access. Culverts must be constructed where hose lines intersect roadways to facilitate vehicle movement. Access must be provided to the pumps and near each tank berm.

(3) Fire-Suppression Equipment. A wheel-mounted fire extinguisher should be located near each tank berm, fuel-dispensing assembly, and tanker-truck receipt assembly and at the contaminated-fuel module. Extra units should be at a central point ready for use anywhere in the TPT. Covered shelters or containers for housing the kevlar fire-fighting clothing and extra fire-fighting supplies should be at central, easily accessible locations around the TPT. A 20-pound, hand-held fire extinguisher should beat each pump, floodlight set, and fuel-dispensing area and at other operating areas, as determined by the operating supervisor. Personnel must know where all of the fire-fighting equipment is at all times to prevent confusion in an emergency. Visible signs indicating the locations of fire extinguishers would be appropriate.

(4) Floodlight Sets. These sets should be in the fuel-dispensing areas, fuel-receipt areas, and heavy operating areas around the pumps and the switching manifold.

b. *Tank-Farm-Assembly (Module) Layouts.* Due to different site conditions and operational requirements, one layout design for the tank-farm modules in a TPT is not possible. The installation

group modifies the layout, as necessary. Use these layouts as guidelines towards establishing an actual layout for most field situations.

(1) Area. The location of the 210,000-gallon tanks and their berms is the controlling factor in selecting a TPT site and layout. The recommended spacing between the tanks is at least 50 feet. Setting these tank locations defines the rest of the layout. Variations will occur due to uneven terrain, obstacles to be bypassed, and differences in hose sections caused by specification length tolerances. The following lists recommended spacing for tanks and berms:

- Pairs of tanks with a common berm wall need a cleared, level area about 215 feet square for each pair. When using sandbags to construct the berm, the area requirement is about 190 by 100 feet.
- Tanks with individual berms need an area for the tank and berm about 115 feet square. When using sandbags, the area requirement is about 100 feet square.

Figure 7-12 (page 7-18) shows a layout that has limited space or a shortage of berm material; pairs of 210,000-gallon tanks share a berm. Figure 7-13 (page 7-19) shows a layout that has sufficient space and berm material; each 210,000-gallon tank has its own berm. If layout changes are made, valve locations must remain unchanged from those shown on the typical layouts. If the relationships between valves are changed, the operating instructions must be changed accordingly, and all operating personnel notified.

(2) Elevation. Tank elevation relative to the rest of the TPT is important in tank location. To allow for high vapor-pressure fuels, try to keep the tank bottom and suction pump pad at the same level to maximize the suction head available to the pump. If you have to install a TPT on sloping terrain, install the tanks on the lower side of the slope to avoid flooding the pump-operating area in case a tank and berm break. Doing so accounts for the safety factor. The pump pad should not be more than two feet higher than the tank pad or it may be difficult to pump the tank dry when required.

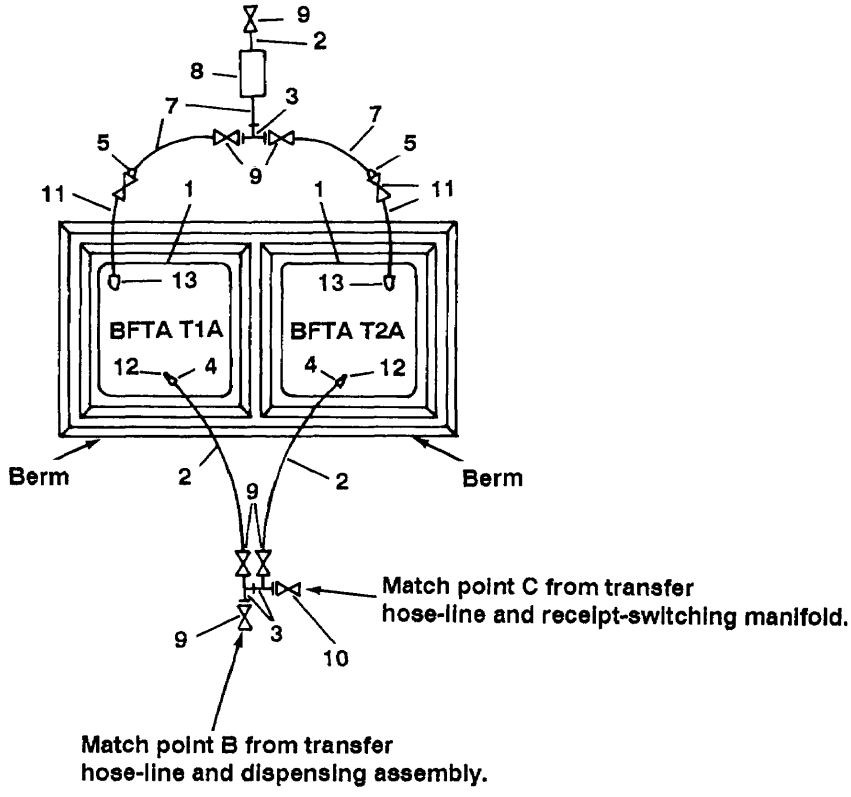
c. Contaminated-Fuel-Module Layout. Place this layout (Figure 7-14, page 7-20) between the associated pipeline and the switching manifold.

(1) Area. Two 50,000-gallon, collapsible fabric tanks with separate berms will each require a level area of about 60 by 100 feet (46 by 87 feet when using sandbags). If the tanks share a berm, the area should be about 105 by 100 feet (96 by 87 feet when using sandbags). Allow space for the 350-GPM transfer pump used with the contaminated-fuel module.

(2) Access. There must be road access to the contaminated-fuel module so tanker trucks can load from the 50,000-gallon tanks, as required. The graded area should be about 40 by 100 feet.

d. *Fuel-Dispensing-Assembly Layout.* This layout (Figure 7-15, page 7-21) is about 525 feet long. A 50- by 600-foot (minimum) section should be graded for the assembly. A graded area about 120 by 700 feet for traffic and parking while loading should be next to the assembly area.

e. *Tanker-Truck Receipt-Manifold Layout* This layout (Figure 7-16, page 7-22) may be off to one side of the switching manifold or next to the fuel-dispensing assembly. A 6-inch hose line from the transfer hose-line assembly connects the tanker-truck receipt manifold to the switching manifold. Using a hose line gives flexibility to locating the receipt manifold.



Parts List

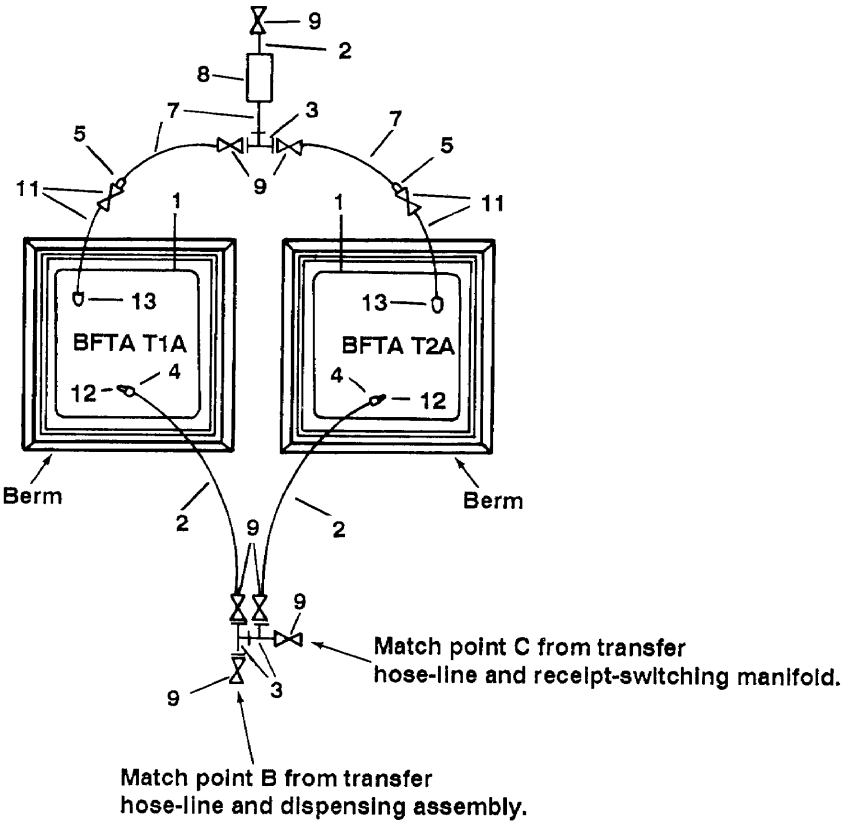
1. 210,000-BFTA.
2. 6-inch hose assembly, discharge, collapsible, 50 feet long. See Note 2.
3. 6-inch aluminum *T*.
4. Coupling adapter, cam-lock, male-by-double-grooved pipe, 6-inch nominal size.
5. Coupling adapter, cam-lock, female-by-double-grooved pipe, 6-inch nominal size.
6. Coupling half gasket, 6-inch nominal size.
7. 6-inch hose assembly, suction, noncollapsible, 12 feet long. See Note 2.
8. 600-GPM hose-line pump.
9. 6-inch aluminum gate-valve assembly, double-grooved ends.
10. 6-inch coupling clamp set, double-grooved.
11. 6-inch hose and gate-valve assembly, noncollapsible, 10 feet long, cam-lock end connections. Over packed with 210,000-gallon tank.
12. Elbow, female-to-female, 6" by 90° size, over packed with 210,000-gallon tank.
13. Elbow, female-to-male, 6" by 90° size, over packed with 210,000-gallon tank.

Notes:
1. Installation of T3A, T4A, P2A, T5A, T6A, and P3A will be the same.
2. The hose line available is constructed with either bands or bolt-on clamps.
3. Coupling clamps are not shown on drawing.

Figure 7-12. Tank-farm layout, shared berm

(1) Area. The recommended graded area is about 120 by 700 feet.

(2) Road Access. Road access is important because heavy truck traffic will occur in this area of the TPT.



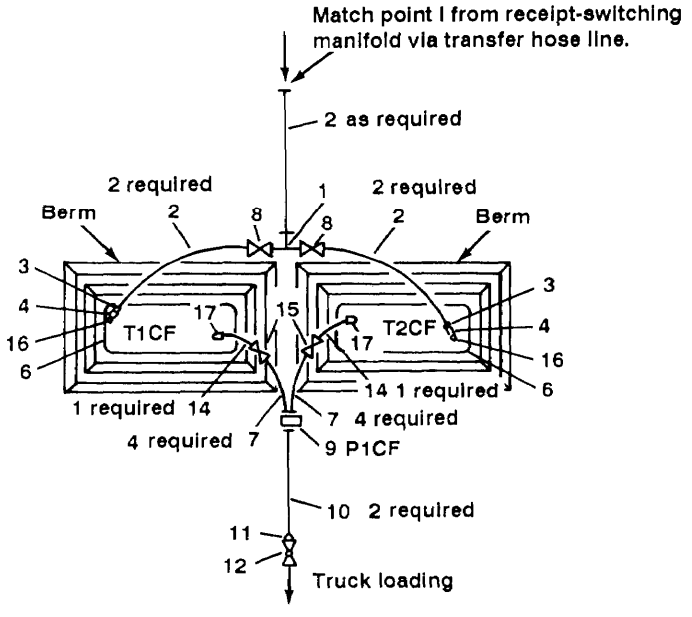
Parts List

1. 210,000-BFTA.
2. 6-inch hose assembly, discharge, collapsible, 50 feet long. See Note 2.
3. 6-inch aluminum *T*.
4. Coupling adapter, cam-lock, male-by-double-grooved pipe, 6-inch nominal size.
5. Coupling adapter, cam-lock, female-by-double-grooved pipe, 6-inch nominal size.
6. Coupling half gasket, 6-inch nominal size.
7. 6-inch hose assembly, suction, noncollapsible, 12 feet long. See Note 2.
8. 600-GPM hose-line pump.
9. 6-inch aluminum gate-valve assembly, double-grooved ends.
10. 6-inch coupling clamp set, double-grooved.
11. 6-inch hose and gate-valve assembly, noncollapsible, 10 feet long, cam-lock end connections. Over packed with 210,000-gallon tank.
12. Elbow, female-to-female, 6" by 90° size, over packed with 210,000-gallon tank.
13. Elbow, female-to-male, 6" by 90° size, over packed with 210,000-gallon tank.

Notes:
1. Installation of T3A, T4A, P2A, T5A, T6A, and P3A will be the same.
2. The hose line available is constructed with either bands or bolt-on clamps.
3. Coupling clamps are not shown on drawing.

Figure 7-13. Tank-farm layout, separate berms

f. *Optional Configuration Layout.* Included in this layout are 50,000-gallon, fabric, collapsible tanks (maximum of six) and the valves, hoses, and fittings to connect them. Use the tanks to replace or supplement the 210,000-gallon tanks or place them in a separate area. Figure 7-17 (page 7-23) shows a layout using six tanks. Each pair of tanks requires a level area about 105 by 100 feet (96 by 87 feet when using sandbags). If the site has less than six tanks, modify the layout.



Parts List

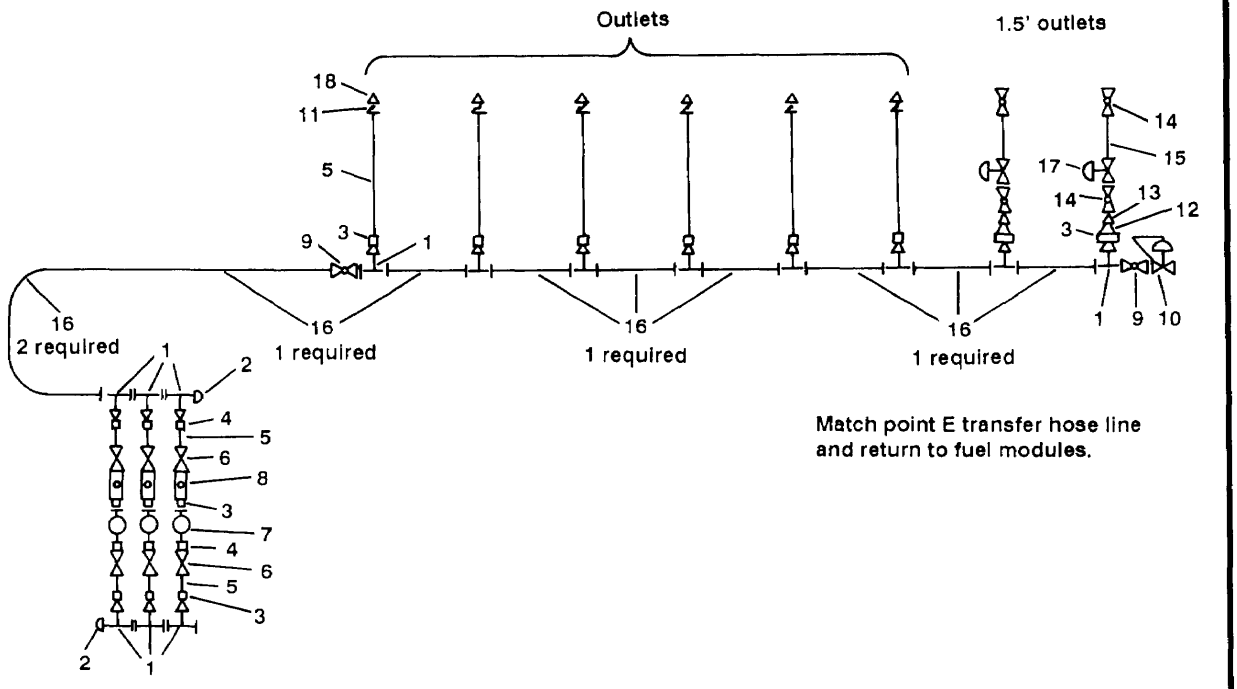
1. 6-inch aluminum *T*, double-grooved.
2. 6-inch hose assembly, discharge, collapsible, 500 feet long.
3. Coupling adapter, cam-lock, male-by-double-grooved pipe, 6-inch nominal size.
4. Reducer, cam-lock, 6-inch female by 4-inch male.
5. Coupling half gasket, 6-inch nominal size.
6. 50,000-gallon, fabric collapsible tank.
7. 4-inch hose assembly, suction, noncollapsible, 12 feet long.
8. 6-inch gate-valve assembly, double-grooved.
9. 350-GPM transfer pump.
10. 4-inch hose assembly, discharge, collapsible, 12 feet long.
11. Reducer, cam-lock, 4-inch female by 3-inch male.
12. 3-inch ball valve assembly.
13. 6-inch coupling clamp set, double-grooved.
14. 4-inch hose assembly suction, noncollapsible, 10 feet long, over packed with 50,000-gallon tank.
15. 4-inch gate-valve assembly, over packed with 50,000-gallon tank.
16. Elbow, female-to-female, 4-inch by 90° size, over packed with 50,000-gallon tank.
17. Elbow, female-to-male, 4-inch by 90° size, over packed with 50,000-gallon tank.

Notes:
1. These are spare 50-foot-long hose assemblies taken from the tank-farm (module) assemblies.
2. Coupling clamps are not shown on drawing.

Figure 7-14. Contaminated-fuel-module layout

g. *Typical Pad and Berm Design.* All tanks are installed on pads inside berms to contain spills and isolate fires that result from spills. Figure 7-18 (page 7-24) shows a basic design for tank berms and pads.

(1) Site Selection. Carefully select the sites for the tanks and their berms. You should consider space, terrain, soil consistency, and accessibility. Once you select the site, clear and grade it so that the final tank pad will have about a 10-degree slope toward the drain assembly closest to the tank's pump-suction fitting. This will minimize the amount of fuel remaining after full pump down. Remove all sharp objects, rocks, sticks, and so forth that might puncture the fabric tanks.

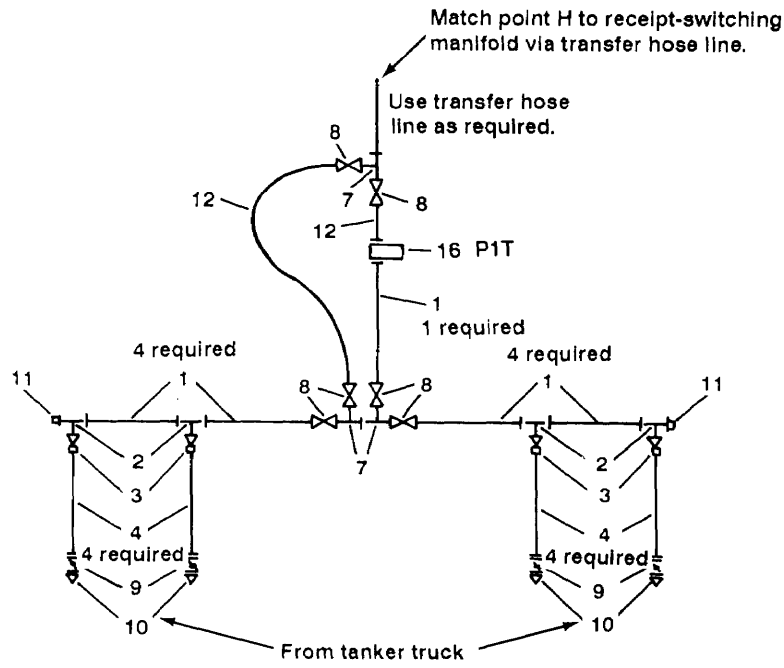


Parts List

1. *T*, reducer, 6" x 6" x 4", double-grooved.
2. 6-inch cap, double-grooved aluminum.
3. Coupling adapter, 4-inch, cam-locking, male-by-grooved-end pipe.
4. Coupling adapter, 4-inch, female-quick-disconnect-by double-grooved end.
5. 4-inch hose assembly, dispensing, collapsible, cam-locking, 25 feet long.
6. 4-inch gate-valve assembly, cam-locking.
7. Filter, separator, 350-GPM.
8. Adapter, for water-detection kit.
9. 6-inch ball-valve assembly, double-grooved.
10. 6-inch valve assembly, pressure control, double-grooved.
11. 4-inch butterfly-valve assembly, cam-locking, female-by-female.
12. Reducer, cam-locking, 4-inch female by 2-inch male.
13. Reducer, cam-locking, 2-inch female by 5-inch male.
14. 1.5-inch ball-valve assembly, cam-locking.
15. 1.5-inch hose assembly, dispensing, collapsible, 25 feet long.
16. 6-inch hose assembly, dispensing, collapsible, 50 feet long.
17. 1.5-inch pressure-control valve.
18. Reducer, cam-locking, 3-inch female by 4-inch male.
19. 6-inch double-grooved, coupling clamp set.
20. 4-inch coupling half gasket, cam-locking type.
21. 2-inch coupling half gasket, cam-locking type.
22. 3-inch coupling half gasket, cam-locking type.
23. 4-inch coupling clamp, grooved-end pipe.
24. 4-inch rubber gasket.
25. 6-foot ground rod with 12-foot cable.
26. Fuel system supply point, coupling, kit, NATO.

Note:
Coupling clamps are not shown on this drawing.

Figure 7-15. Fuel-dispensing-assembly layout



Parts List

1. 6-inch hose assembly, suction, noncollapsible, 12 feet long.
2. *T*, 6- by 6- by 4-inch, double-grooved, aluminum.
3. 4-inch coupling adapter, cam-lock, male-by-grooved-end pipe.
4. 4-inch hose assembly, suction, noncollapsible, 12 feet long.
5. 4-inch coupling clamp, grooved-end pipe.
6. Gasket, 4-inch, synthetic rubber.
7. 6-inch aluminum *T*, double-grooved.
8. 6-inch aluminum gate valve, double-grooved.
9. 4-inch butterfly-valve assembly, cam-locking, female-by-female.
10. Reducer, cam-locking, 3-inch female by 4-inch male.
11. 6-inch, double-grooved aluminum cap.
12. 6-inch hose assembly, discharge, collapsible, 50 feet long.
13. 6-inch coupling clamp, double-grooved.
14. 6-foot-long, self-driving ground rod with 12-foot cable.
15. NATO rail tank-car coupling.
16. NATO tank-truck adapter coupling set.
17. 600-GPM hose-line pump from TPT support assembly.

Note:
Coupling clamps are not shown on this drawing.

Figure 7-16. Tanker-truck receipt-manifold layout

(2) Construction Materials.

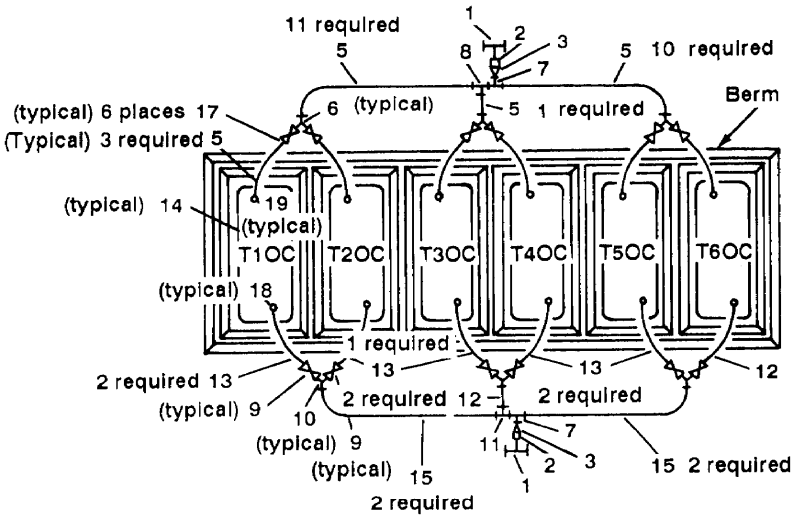
(a) Earth. Berms are normally constructed of earth from the surrounding area. The more impermeable the soil, the better. A high clay content is best to avoid leaks and keep the berm in shape. Some rock and gravel content is okay, since it will tend to avoid washout.

(b) Sandbags. You can use sandbags to construct berms if site conditions preclude earth construction. However, sandbag berms will not hold a tank spill very well unless you seal the gaps

between bag ends. Heavy clay packing between joints will help, but considerable leakage can take place. Sandbags are supplied with the TPT.

(3) Liners.

(a) Low-density polyethylene. Tank pads and berms may be lined with a heavy gauge plastic sheeting if soil permeability is a problem at the site. Construction-grade, low-density polyethylene, preferably with a fiber net molded in, is acceptable. Take care to adequately overlap and, if possible, seal the joints. Low-density polyethylene can be heat-sealed at the joints if time and site conditions permit before the fuel arrives.



Parts List

1. 6-inch *T*, double-grooved aluminum.
2. Coupling adapter, cam-locking, male-by-double-grooved pipe, 6-inch nominal size.
3. Reducer, cam-locking, 6-inch female by 4-inch male.
4. Gasket-coupling half, quick disconnect, cam-locking type, 6-inch nominal size.
5. 4-inch hose assembly, suction, noncollapsible, 12 feet long.
6. 4-inch *Y*-assembly, cam-locking, one male and two female connections.
7. 4-inch *T*-assembly, cam-locking, one male and two female connections.
8. 4-inch *T*-assembly, cam-locking, three female connections.
9. 4-inch gate-valve assembly, cam-locking connections.
10. 4-inch *Y*-assembly, cam-locking, one female and two male connections.
11. 4-inch *T*-assembly, cam-locking, three male connections.
12. 4-inch hose assembly, discharge collapsible, 12 feet long.
13. 4-inch hose assembly, dispensing, collapsible, 25 feet long.
14. 50,000-gallon fabric tank.
15. 4-inch hose assembly, discharge, collapsible, 50 feet long.
16. Coupling clamp set, 6-inch, double-grooved, boltless.
17. 4-inch hose assembly, suction, noncollapsible, 10 feet long, over packed with 50,000-gallon tank (4-inch gate valve included.)
18. Elbow, female-to-female, 4-inch by 90° size, over packed with 50,000-gallon tank.
19. Elbow, female-to-male, 4-inch by 90° size, over packed with 50,000-gallon tank.

Note:
Coupling clamps shown on this drawing.

Figure 7-17. 50,000-gallon-tank layout

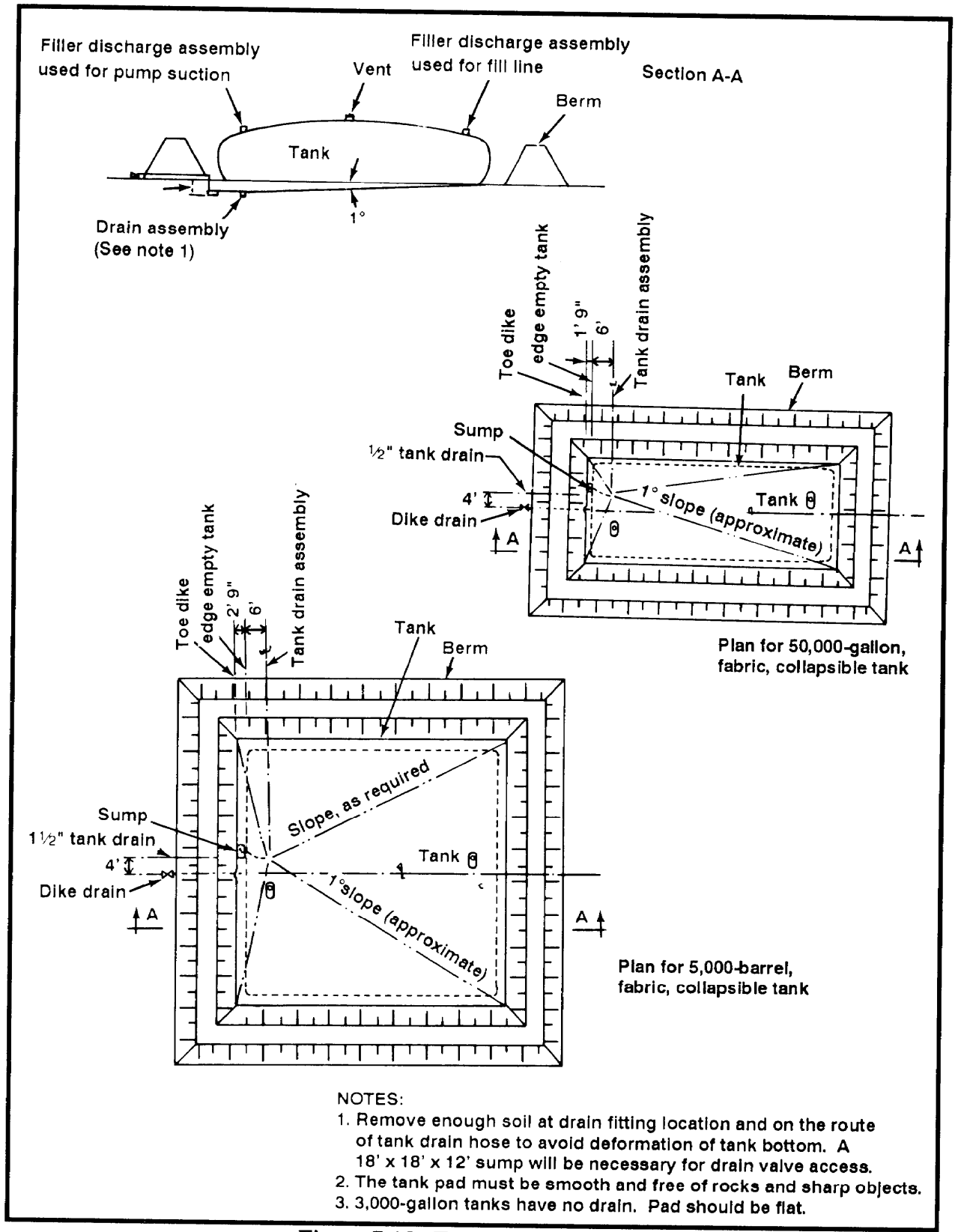


Figure 7-18. Tank and pad layout

Another sealing method is to tape the joint with 2- to 4-inch, self- adhering plastic tape. A light earth or sand fill over the liner, particularly over the tank pad, is recommended. If you use a drain line that penetrates the berm, pierce a section of the liner and tie it tightly with synthetic cord around the drain pipe to avoid a washout or leak. You can also use plastic self-adhering tape that overlaps the liner and the drain pipe. Sealing tape and plastic sheeting are not supplied with the TPT.

(b) Prefabricated polyethylene. In certain environmental situations, you may procure a prefabricated, polyethylene berm liner, as authorized by the government. These liners are--

- Size 4, 50,000-gallon.
- Size 5, 210,000-gallon.

(4) 210,000-Gallon Tank. The dimensions of the tank and the minimum berm size are--

- Empty tank: 68 feet 6 inches by 68 feet by 6 inches.
- Filled tank: 66 feet by 66 feet by 6 feet 8 inches.
- From toe of berm to tank wall when filled: 4 feet.
- Berm height, to contain full tank with 1-foot freeboard: 5 feet 6 inches.

(5) 50,000-Gallon Tank. The dimensions of the tank and the minimum berm size are--

- Empty tank: 26 by 66 feet.
- Filled tank: 24 feet by 64 feet by 5 feet 8 inches.
- From toe of berm to tank wall when filled: 3 feet.
- Berm height, to contain full tank with 1-foot freeboard: 4 feet 6 inches.

(6) Berm Basin Drain. To provide a berm basin drain, install a 2-inch or larger pipe with a gate valve (used pipe and valves of any rating are acceptable) on the outside end in the bottom of the berm at the lowest end of the tank pad. The valve must be in the closed position. Open the valve only to drain water from the bermed area. If you do not install a drain, you may have to pump the basin inside the berms periodically, depending on the permeability of the soils and whether or not a sealing liner is installed. Drain pipe and valves are not supplied with the TPT.

Appendix A. Formulas

This appendix contains the formulas you can use during pipeline design and operations.

A-1. Conversion Formulas.

a. *Pressure (psi) to Head (Feet)/Head to Pressure.*

$$pressure = \frac{(head)(specific\ gravity)}{2.31}$$ **or** $pressure = (0.433)(head)(specific\ gravity)$

and

$$head = \frac{(2.31)(pressure)}{specific\ gravity}$$ **or** $$head = \frac{psi}{(0.433)(specific\ gravity)}$$

Conversion constant; 1 psi= 2.31 feet of head of water at 70°F.

b. *Degrees API to Specific Gravity/Specific Gravity to Degrees API.*

$$API\ at\ 60°\ F = \frac{141.5}{specific\ gravity\ at\ 60°\ F} - 131.5$$

and

$$specific\ gravity\ at\ 60°\ F = \frac{141.5}{degrees\ API\ at\ 60°\ F + 131.5}$$

A-2. Bernoulli Equation. This equation expresses the energy relationship for a liquid flowing through a pipe between two points.

$$\frac{P_1}{W} + Z_1 + \frac{V_1^2}{2g} + H_a = \frac{P_2}{W} + Z_2 + \frac{V_2^2}{2g} + H_f$$

where =

P = pressure, in pounds per square foot.
W = specific weight, in pounds per square foot.
Z = elevation, in feet.
V = velocity of flow, in feet per second.
g = acceleration of gravity, 32.2 square feet per second.
H_a *= head added by pump between points, in feet.*
H_f *= head loss due to friction between points, in feet.*

A-3. Darcy-Weisbach Equation. Use this equation to calculate friction head loss in a pipeline:

$$H_f = \frac{(0.031)\,(f)\,(L)\,(Q^2)}{d^5}$$

where--

H_f = friction head loss, in feet.
f = dimensionless friction factor based on the Reynold's number and the inside roughness of pipe.
L = length of the pipe, in feet.
Q = flow, in GPM.
d = inside diameter of the pipe, in inches.

A-4. Reynold's Number. Use this equation to determine the friction factor required in the Darcy-Weisbach Equation (see Figure C-9, page C-8):

$$\textit{Reynold's number} = \frac{(3{,}160)\,Q}{dK}$$

where--

Q = flow, in GPM
d = inside diameter of pipe, in inches.
K = kinematic viscosity, in centistokes (see Figure C-8, page C-7).

Appendix B. Steel Pipeline Systems

B-1. Equipment.

a. *Steel Pipe.* Steel pipe (light- and standard-gauge wall thickness) is available in 20-foot lengths with diameters of 4, 6, and 8 inches. Steel pipe is coupled using a standard, two-piece split-ring coupling. The coupling uses two half-moon sections, which are bolted together over a one-piece gasket. The average time required to couple together two sections of steel pipe is 5 minutes.

b. *Lightweight Steel Grooved Pipe.* This pipe is made of light gauge steel with API STD5L pipe nipples welded to each end. The pipe ends are single-grooved for use with bolted couplings. This pipe comes in 20-foot sections with 4-, 6-, 8-, and 12-inch nominal IDs. Because of its thin wall, lightweight steel pipe should not be buried nor used for submerged stream crossings or in populated areas and locations where fire and damage hazards are acute.

c. *Standard-Weight Steel (API STD5L) Pipe.* This regular commercial-type pipe, which is manufactured to the standards of the API, is used when lightweight pipe or tubing is unavailable or unsuitable. The pipe comes in 20-foot sections grooved for coupling and in random lengths and diameters beveled for welding.

d. *Bolted Coupling.* This is a standard, split-ring, groove-type coupling (Figure B-1, page B-2). It consists of two housing segments; two bolts and nuts; and a synthetic-rubber, oil-resistant, self-sealing gasket. The coupling and gasket are designed so that the pipe joint seals under pressure and vacuum. The coupling provides a sufficient amount of angular deflection and slack adjustment for expansion and contraction of the line between adjacent joints.

When using bolted couplings, the crew consists of a crew leader, wrenchman, wrenchman's helper, stabber, jackman, swabber, and pipe-end cleaner. The bolted-coupling crew will normally require--

- Two 20-inch hinged socket wrench handles.
- Two sockets to fit size of pipeline coupling nut and wrench.
- File.
- Dauber brush.
- Lazy board.
- Two pipeline jacks with two snakes.
- Pipeline cleaner swab with one snake.
- Wooden blocks (4 by 4 by 10 inches) with carrying rope attached.
- Full half-gallon bucket or one-gallon bucket half filled with GAA grease.
- Cleaning rags.

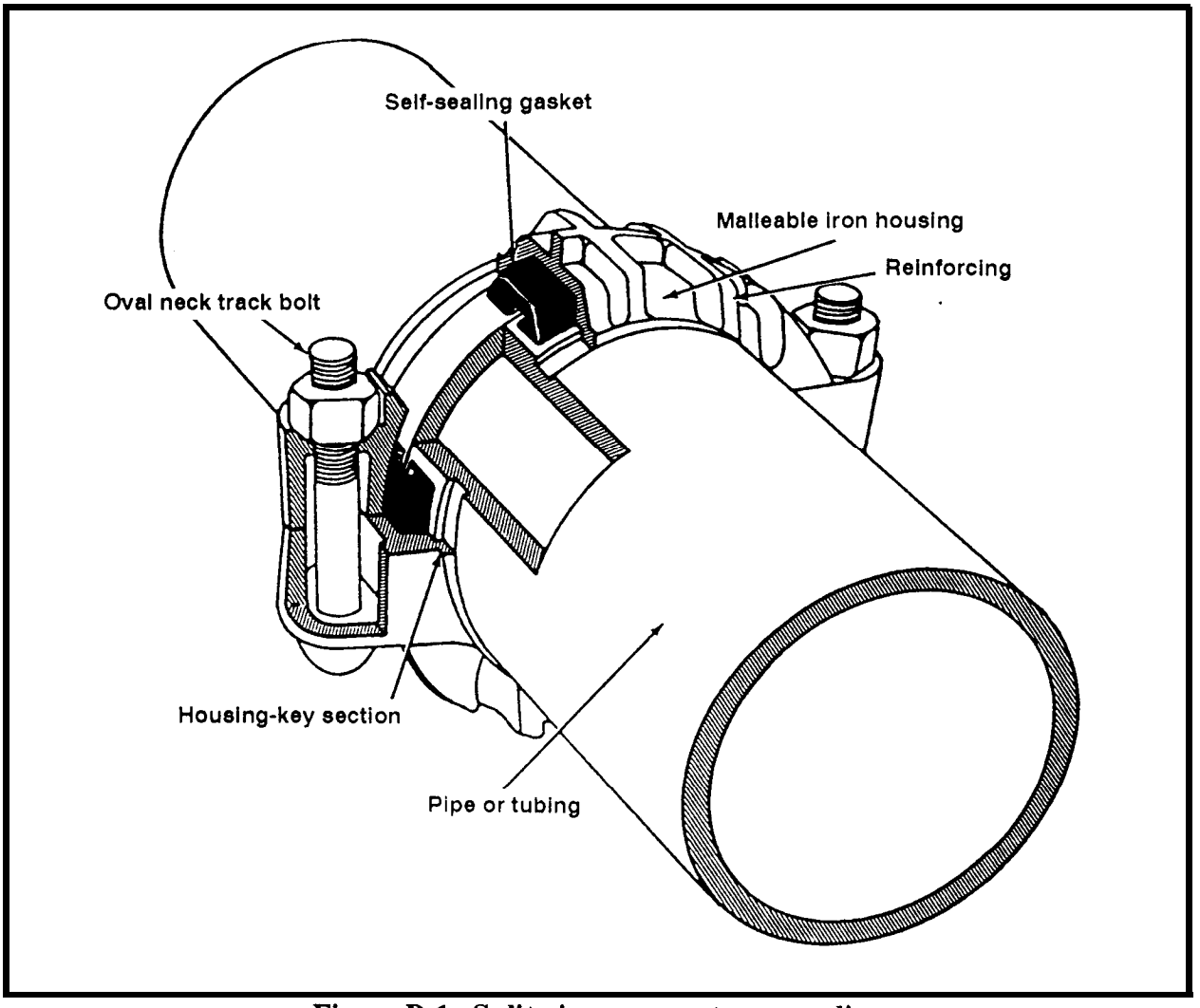


Figure B-1. Split-ring, groove-type coupling

e. *Pipe Saw, 8-Inch Capacity for Hazardous Locations.* This is a reciprocating-type saw powered by an air motor. You can cut steel, cast iron, and stainless or alloy steel pipe as well as bar stock structural and rail. Use this saw to cut out a damaged portion of pipeline when operating in hazardous locations. You can operate when clearances are at minimum and you can make a straight, right-angle cut.

f. *Tapping Machine.* This machine is used for tapping into a pressurized pipeline to establish a service tap or to install a pressure-relief device. This operation can be done without shutting down the pipeline system. The machine uses a hole saw; a holder-pilot performs the cutting operation. He retains the separated pipe after he completes the cut and allows for its removal.

The tapping machine is lightweight and easy to operate and has an adjustable automatic-feed rate for any cutting condition. The advance rate for cutting is set by the feed-adjustment knob. This knob engages a friction-type clutch that automatically regulates the feed rate. The operator loosens (slow feed) or tightens (faster feed) the feed-adjustment knob to obtain the correct amount of force for the task. The machine comes with a ratchet crank for manual operation.

g. *Deadweight Tester.* This tester is used to calibrate pressure gauges, verify the set points of spring-loaded relief valves, and provide precise pressure readings for pipelines. The tester uses known weights that directly correlate to known pressure gauges and the verification of set points for spring-loaded relief valves.

B-2. Coupling Procedures.

a. *For 8-inch Steel Tubing.* Procedures for this tubing, because of weight (210-pound tubing), are different than for lighter pipelines. A saddle-type carrying bar (Figure B-2) and one extra person in the crew are required for constructing the 8-inch tubing pipeline. This extra person is a second helper who assists in raising the new section onto the lineup cage and in lowering it. The rest of the coupling operations are the same as those for a 4- or 6-inch line. Except for size, the 8-inch lineup cage and pipe-cleaner swab are identical to those used on the smaller pipe. Coupling procedures for 8-inch steel tubing are as follows:

- The second helper assists the wrenchman's helper to raise their end of the tubing section and guide it onto the lineup cage, while the stabber and jackman handle the other end.
- The second helper moves to the other end and assists the jackman and stabber in aligning the section, as directed by the wrenchman.
- The second helper assists the jackman and stabber in lowering the new end of the pipeline on the lazy board. Then the second helper assists the wrenchman's helper with the next section.

b. *For 8- and 12-Inch Standard Steel Pipe and 12-Inch Steel Tubing.* Do not manually handle pipe sections heavier than the 6-inch (300-pound) standard-weight pipe. Use powered equipment to off-load the pipe and couple one section at a time. You can stockpile the pipe along the pipeline trace. If you do, use a pipelayer (Figure B-3, page B-4) to handle the pipe. (The pipelayer is a commercial piece of equipment that must be leased.)

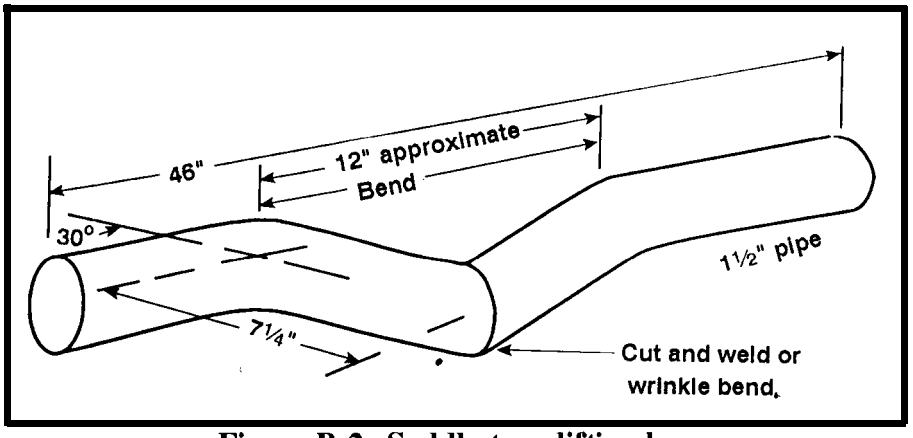


Figure B-2. Saddle-type lifting bar

(1) Swabbing and Cleaning. The swabber and pipe-end cleaner swab all of the pipe on a load, one row at a time, in a single operation. (They can swab the pipe while it is still on the truck or in a stockpile.) With one man at each end, they insert a snake in either outside pipe of the top row and pass it through to the other end. The man at the end where the snake is coming through pulls it through the first pipe and simultaneously feeds the snake back through the next pipe in the row. The men repeat this operation until they swab all the pipes (Figure B-4, page B-5).

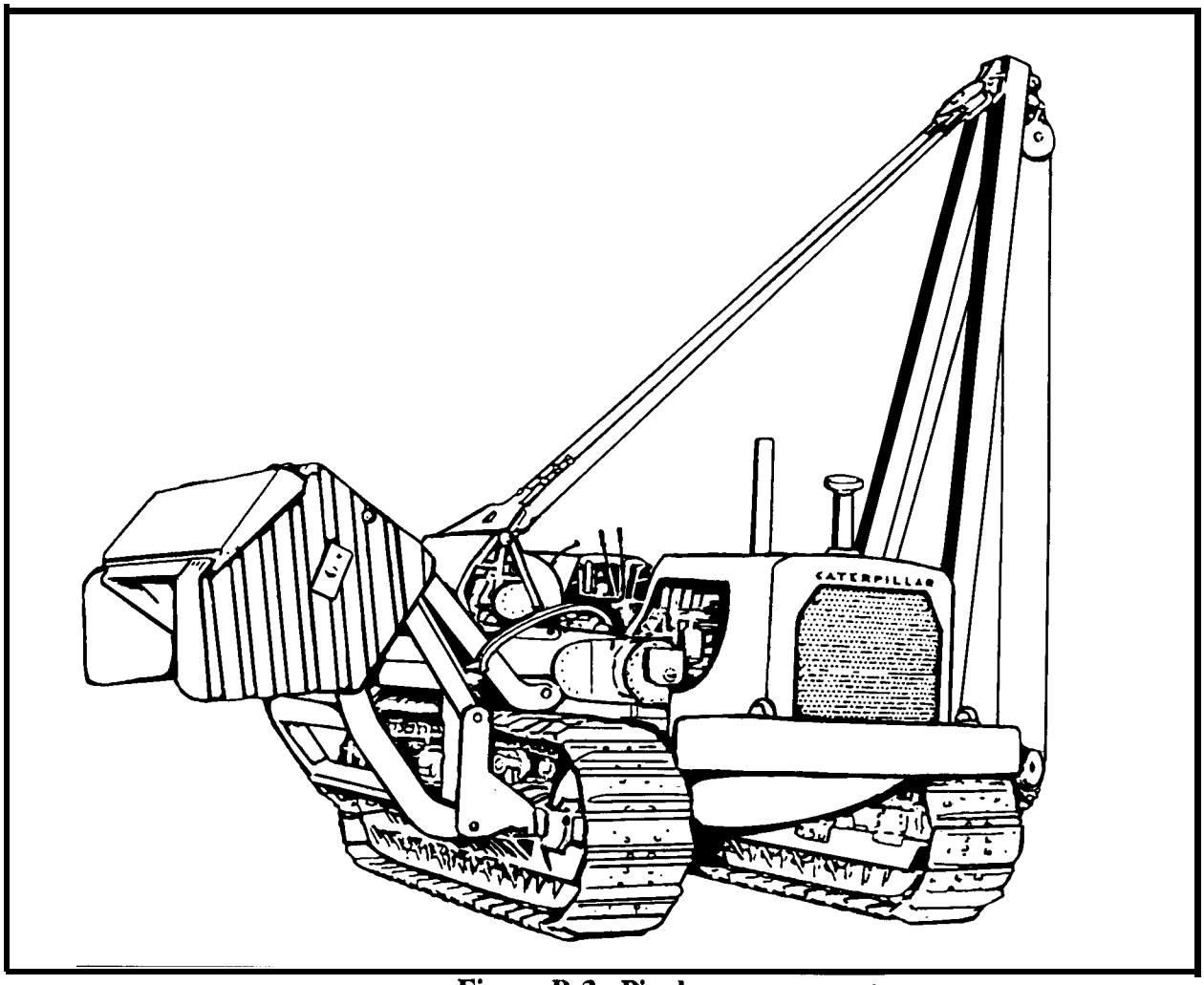


Figure B-3. Pipelayer

(2) Moving the Pipe. The pipe is picked in the middle with an automatic clam-type release hook attached to the hoisting line of the stringing boom. The pipe joint is first raised only a few inches from the pipe. The swabber and pipe-end cleaner, working at opposite ends, clean and file the pipe land and groove on each end at the same time. At the same time, the wrenchman and helper (one team) and the jackman and stabber (another team) construct cribbing of 4- by 4-inch by 3-foot-long blocks. This cribbing takes the place of the lazy board and pipe jack. Each of the blocks is tied together with rope. Doing so allows the wrenchman's helper to drag one cribbing set at a time when moving it to the next location.

(3) Positioning the Pipe. After the pipe ends are cleaned, the pipe section is swung into approximate alignment on the pipeline. The stabber inserts the lineup-cage snake through it (only one snake is used). The jackman and wrenchman's helper guide the pipe joint into position on the lineup cage protruding from the end of the line. The stringing-boom operator raises or lowers the load and extends or retracts the boom, as directed by the stabber or wrenchman. Once aligned, the jackman keeps the joint aligned by leaning or shoving against the end.

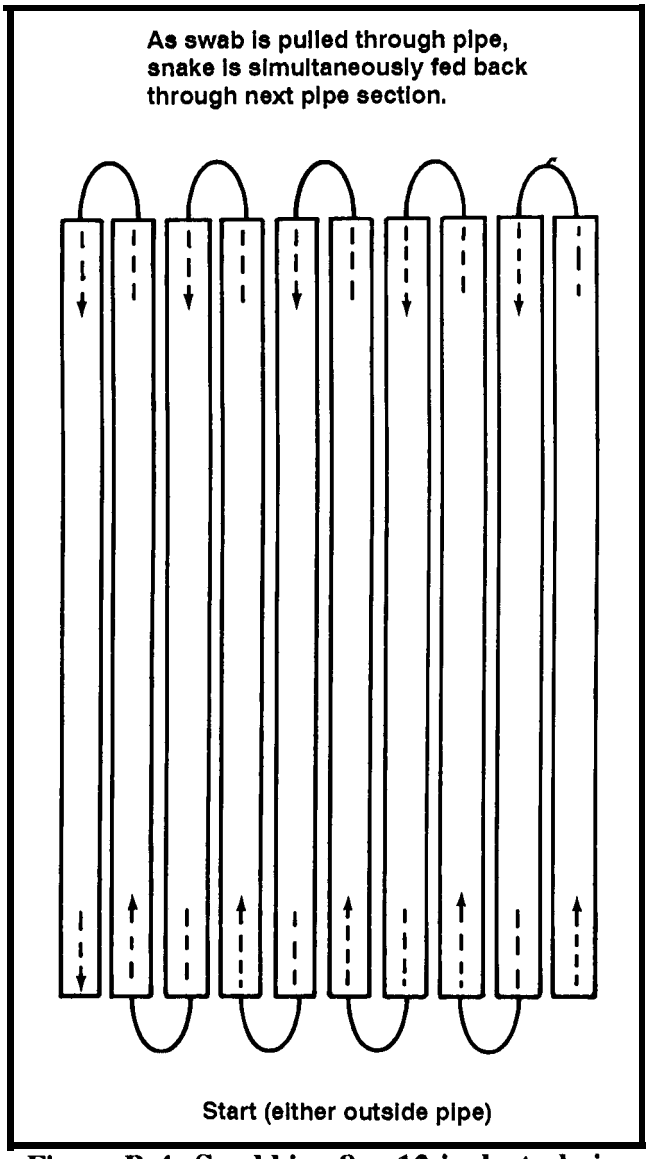


Figure B-4. Swabbing 8- x 12-inch steel pipe

(4) Installing the Coupling. After tightening the coupling, the crew lifts the pipeline high enough so they can pull the cribbing stack out from under the pipeline and drag it forward (about 40 feet) to the far end of where they will install the next section. The jackman lowers the pipeline and guides it onto the cribbing stack. At the same time the stabber places the gasket inside out on the end of the pipeline. As soon as the coupling is tightened, the stabber pulls the lineup cage forward. The stabber erects the cribbing stacks while couplings are installed. As he moves forward, the wrenchman releases the pipe lifting tongs so that the pipe-stringing boom will swing back to the bolster truck for the next pipe section.

B-3. Expansion and Contraction of Coupled Pipelines. Surface-laid metallic pipe expands and contracts with changing temperatures. Groove-type couplings provide some angular deflection and slack adjustment between each pipe joint. Under normal conditions, the tolerance in the couplings will take care of expansion and contraction in a steel pipeline. However, over flat terrain, long, straight stretches of steel pipeline are subject to accumulated expansion and contraction stresses. In this case, horizontal bends in the line are necessary, meaning the line is snaked from side to side.

B-4. Welded Pipeline Systems. Because constructing a welded pipeline takes time, this system is used only if strength is a critical factor. In developed TOs, existing welded pipeline systems would be converted for military use and would require maintenance and repair. Welded pipelines provide the necessary strength, corrosion resistance, and dependability for buried pipeline, underwater stream crossings, and submarine offshore pipelines. Welded pipeline construction requires a higher degree of craftsmanship than the grooved coupling-type pipeline and specialized equipment. Welding a pipeline is an important operation that requires specially trained pipeline welders. This manual discusses methods of constructing a welded pipeline, not welding techniques. Because of the length of time and skill required, the Army normally does not construct long sections of welded pipeline. Welded construction may be used for dockside and underwater pipelines. However, recently fielded systems, like the 4-mile OPDS (a high-pressure, bottom-layed hose line), are the preferred methods.

a. *Construction Methods.* The method of stringing pipe (loading, hauling, distributing) for welded line construction is similar to that for coupled pipeline construction. Position welding and roll welding take the place of coupling. Welding is done by the shielded electric-arc process. The oxyacetylene process is used for cutting and beveling pipe.

(1) Position Welding. Position welding is the standard method for welding military pipelines and is particularly applicable to welding sags and overbends or making tie-ins. With this method, the pipe remains stationary, and the welder works around the circumference of the pipe. Therefore, the pipe must have a minimum 16-inch clearance (see Figure B-5). When making tie-ins in a trench, dig a bell hole so that the welder can get at the underside of the pipe without undue restraint.

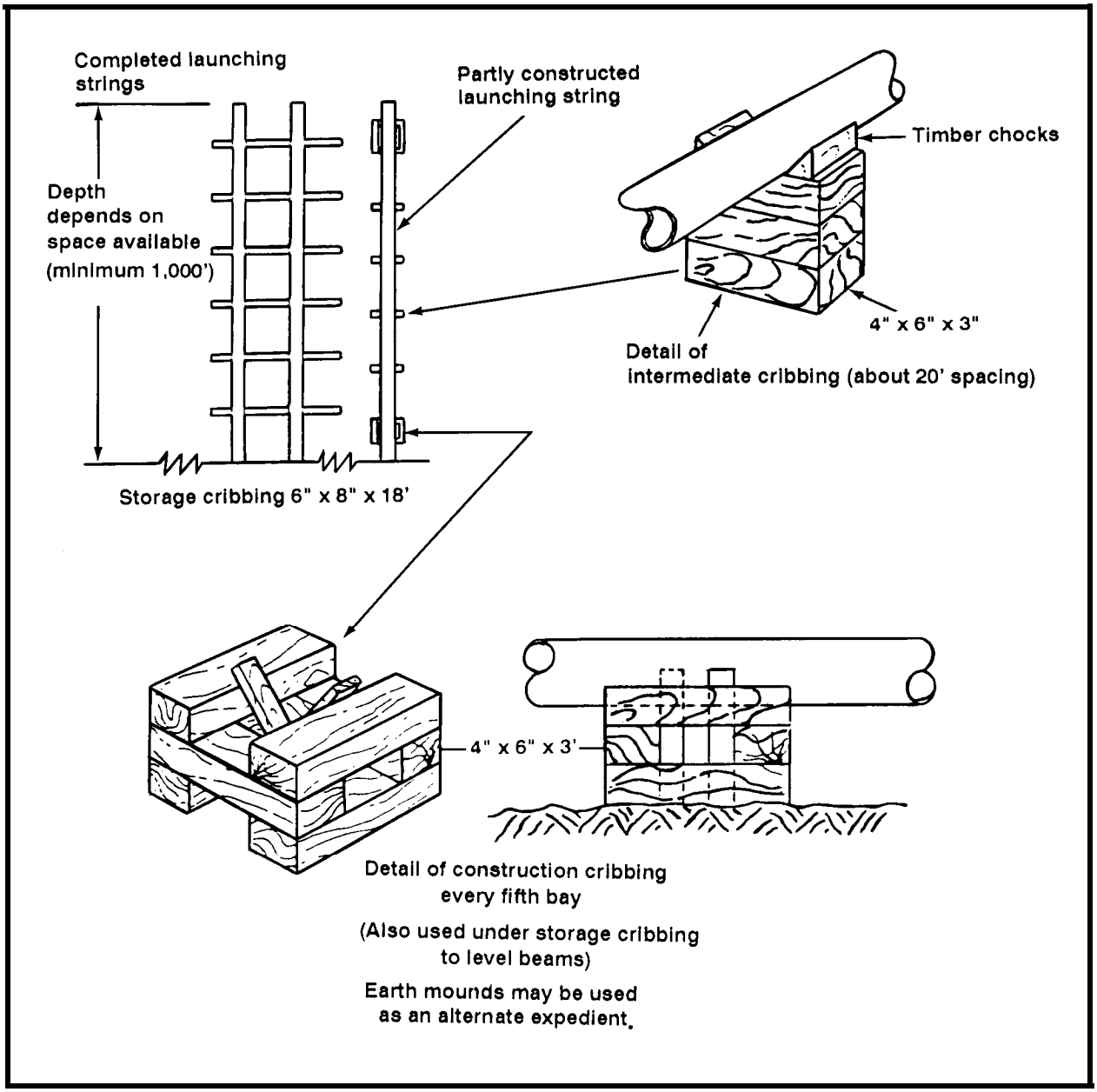


Figure B-5. Cribbing for welding pipelines

(2) Roll Welding. With this method, the pipe is rotated so that the welding is always done at or near top center. Although seldom used in welding military pipelines, this method is sometimes more expedient in welding short strings of line, such as road crossings or manifold systems, or for lines inside of fire walls at tank farms.

b. *Procedures.*

(1) Cleaning. Just before the welding operation, clean the pipe-end bevels of all foreign matter. Do this by filing or brushing or by using portable, motor-driven brushes or grinders. Just before cleaning the pipe-end bevels, swab the pipe to remove any excess dirt, sticks, stones, small animals, or reptiles. If the random length pipe sections are longer than the standard swabbing snakes, lengthen the snakes a few feet by taping or wiring a piece of wire rope on the forward end of the snake. (For double-random sections, make a snake by overlapping and taping two snakes together.)

(2) Rebeveling and Cutting to Length. During handling, the pipe bevel or the end of the pipe may be damaged. Sometimes you may have to cut and bevel a piece of pipe to a certain length. Use an oxyacetylene pipe cutting and beveling machine to rebevel or to cut and bevel. Then use a bevel grinding machine to clean the bevel of slag. Both machines are in the welded pipeline construction tool set.

(3) Aligning Clamps. Producing a satisfactory pipe-joint weld requires exact alignment of the pipe joint. Two types of pipe-joint aligners are available:

- Tipton-type, external, pipe-joint aligning clamps for 4-, 6-, and 8-inch pipe sizes are common to all welded petroleum pipeline construction (see Figure B-6, page B-8). The clamp aligns the pipe joint externally, eliminates almost all out-of-roundness of the pipe ends, and holds the pipe joints in a longitudinal position until at least 50 percent of the stringer bead (stringer pass) is completed.
- Internal-type pipe-joint aligners (Figure B-7, page B-9) produce the required alignment and eliminate the requirement for preliminary tack welds necessary with the external-type lineup clamps.

c. *Standards.*

(1) Use beveled pipe for welded sections of military pipeline. This pipe is furnished with carefully squared ends and beveled edges so that, when placed with ends about 1/16-inch apart, there is a groove all the way around the joint where the welding metal is applied. The groove angle is about 75 degrees for pipe with a wall thickness of 1/4 inch or less; for pipe with a wall thickness of more than 1/4 inch, the groove angle is about 60 degrees (Figure B-8, page B-10).

(2) Use *reverse* polarity (the electrode is positive and the work is negative), if you use shielded arc electrodes. Do not start two welding beads (passes) at the same point on the circumference of the joint. When you complete one bead, remove all scale or slag from the bead, undercut, and groove with a powered wire brush and an ice pick before welding the next bead. Adjust the welding amperage and the arc travel speed accordingly to produce the following welds:

- Filler pass - should be about l/8-inch thick. Run enough beads to provide the reinforcements required for the completed weld.

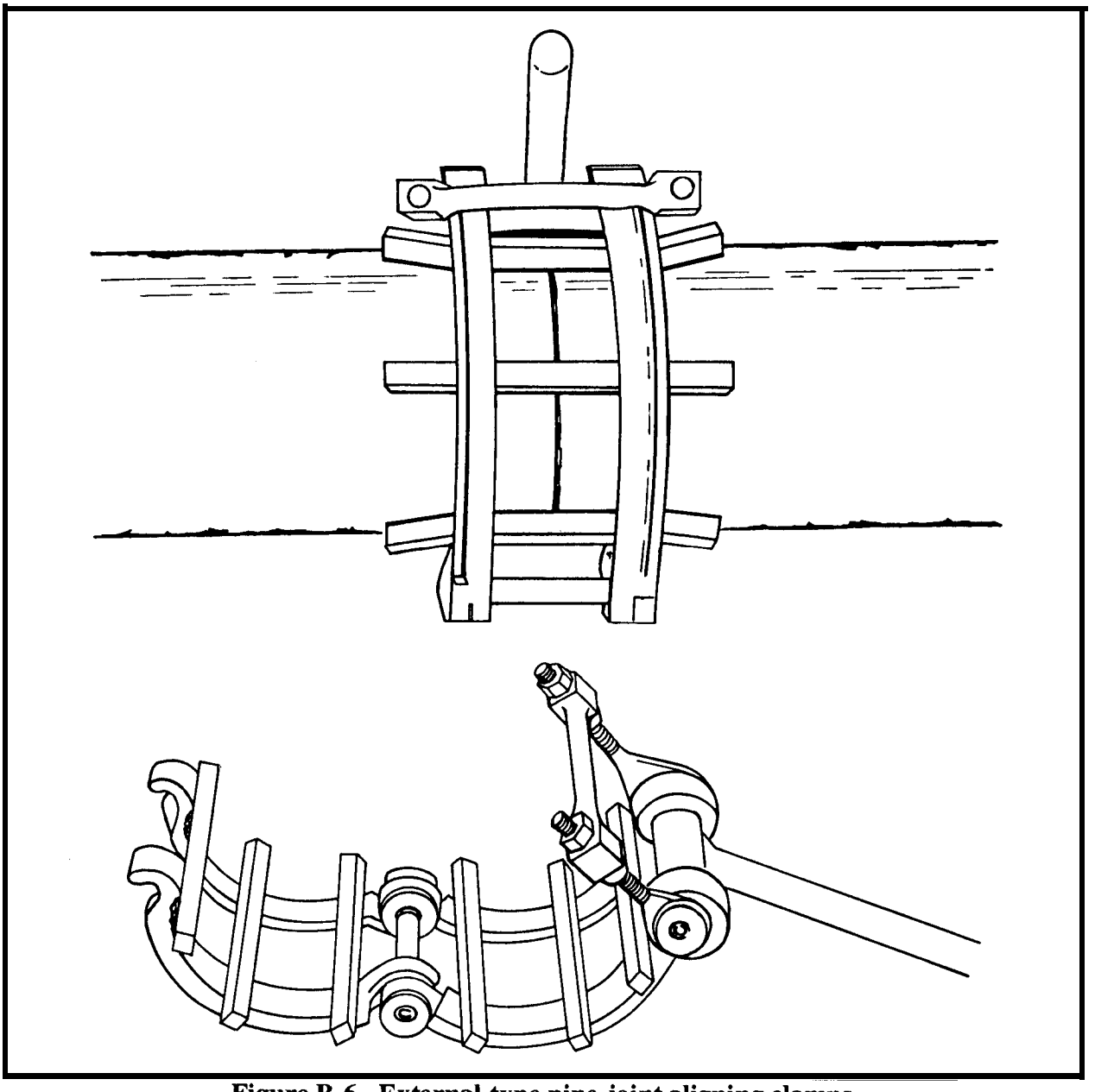


Figure B-6. External-type pipe-joint aligning clamps

- Stringer pass - should provide complete penetration, filling the bottom of the groove with weld metal. Penetration should not be so great as to burn through and blow the weld puddle into the pipe.
- Finish (or cover) pass - should be about 1/8-inch greater that the original groove. Thoroughly fuse the weld metal in each bead to the parent metal of the pipe so it provides a reinforcement of not less than 1/32-inch or more than 1/16-inch above the pipe surface. Thoroughly brush and clean the finished weld.

(3) Remove the full section containing lamination or split ends if you discover such defects during the welding process. Do not use this section of pipe until you repair or remove the defect.

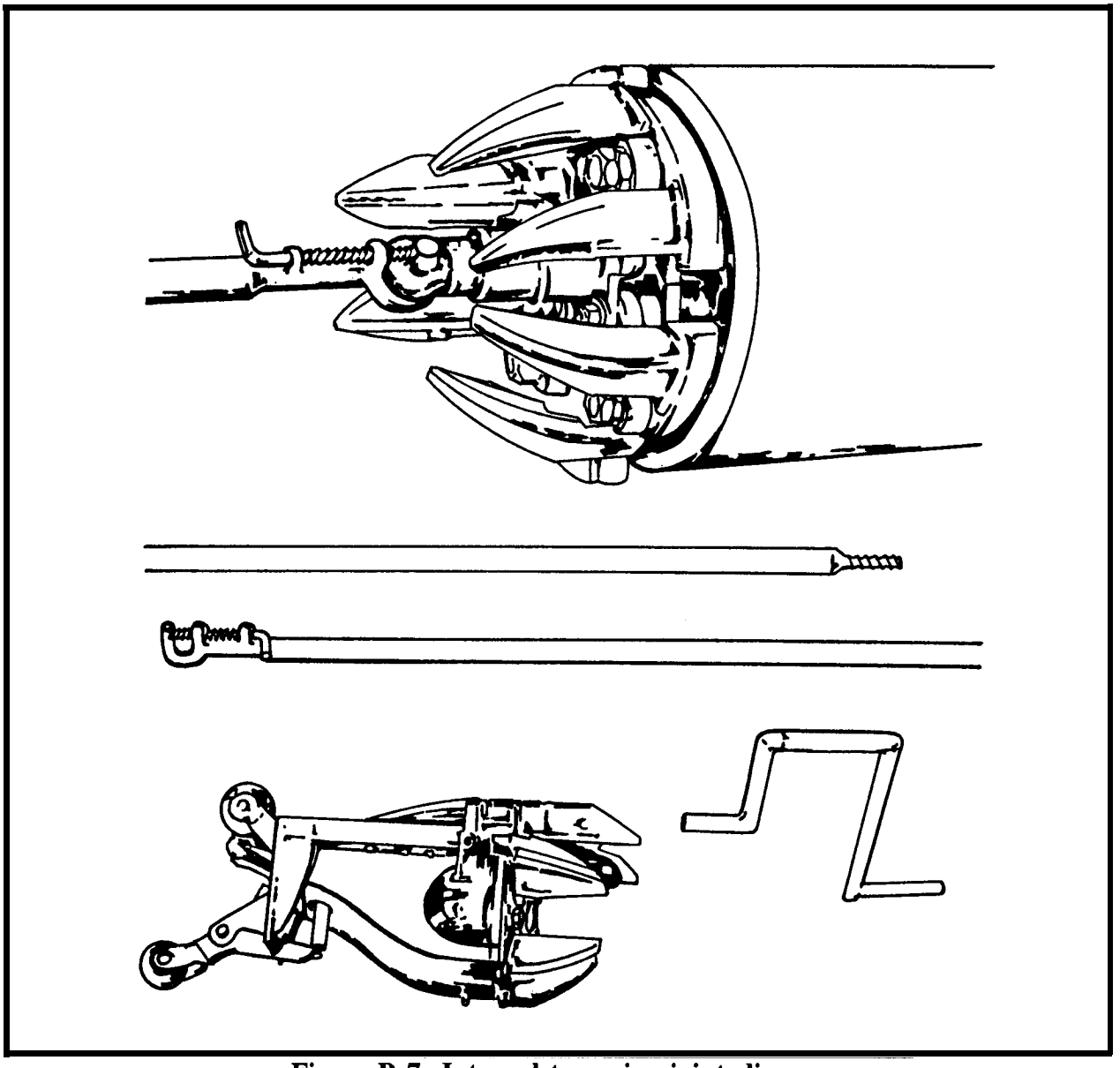


Figure B-7. Internal-type pipe-joint aligners

(4) Rebevel the pipe if the ends are damaged during handling so that you cannot get a satisfactory welding contact. Use a beveling machine on all cuts on ends of line pipe for welding. Freehand bevel cuts of line pipe in preparation for welding are not permitted. After rebeveling, grind the bevel with a bevel grinding machine.

d. *Precautions.* Coated electrodes are subject to deterioration from moisture absorption. Store electrodes in unopened original containers, and protect opened containers from excessive moisture changes. In handling electrodes, avoid damage to the coating. Do not use electrodes that show signs of deterioration or damage.

Do not weld when the quality of the completed weld may be impaired by the prevailing weather conditions, which include airborne moisture, blowing sands, and high winds. Use windshields

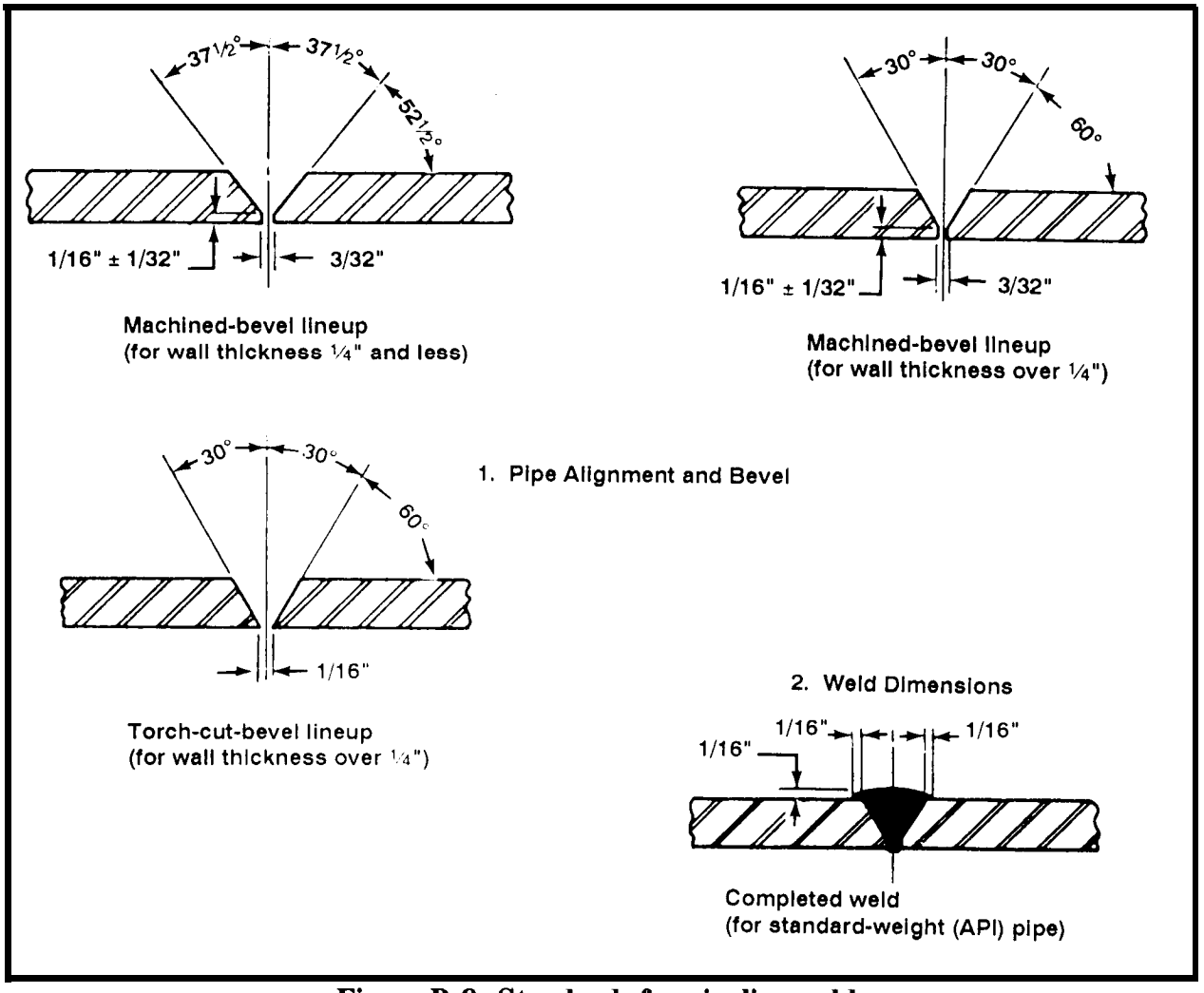


Figure B-8. Standards for pipeline welds

when practicable, and use the umbrella (included in the welder's supplemental pipeline-construction kit) when necessary. In very cold weather (below freezing), preheat the pipe before welding it. If you have to leave an incomplete pipeline section overnight, close the open ends by tack-welding plates or caps so foreign matter or vermin cannot enter.

e. *Tie-Ins.* During most laying operations, you may have unconnected sections of the line. Welding these sections together is known as *tie-ins.* These unwelded sections usually occur because of the following:

- The section of line beneath a road or railroad is not installed by the welding crew.
- The line is not completed at river crossings.
- Crew members would like to have a free section to work on coated lines (lines being prepared for burying) without interfering with welding operations.
- The line is left open for swabbing.

NOTE: Bends must fit the ditch and should not crowd ahead on large diameter lines.

f. *Buried Pipe.* Welded, standard-weight, steel API STD5L pipe is the only type you can bury. Do not use lightweight tubing under any circumstance. Bury pipeline where the line is susceptible to damage if left exposed or where breaks will create a fire hazard to essential military or civilian activity. For example, bury the line--

- At river-crossing approaches, especially where the possibility of flooding could wash away unburied line.
- At road crossings where the line cannot run through existing or improvised culverts.
- In airfield distribution systems.
- In areas where the route passes through cities or other populated areas.
- In cultivated areas.
- In areas where the pipe is on the shoulders of main supply routes. If not buried, this pipe could be broken or crushed by vehicles that go off the road surface.

When planning for buried pipe, contact local civil authorities, utility companies, and commercial organizations through whose property the line will pass. They will advise you of any buried systems or facilities, such as installed cathodic protection systems, that you must avoid.

(1) Construction Standards.

(a) Depth. Bury the pipe deep enough to furnish at least a 2-foot cover of earth as protection against the weight of trucks, tanks, and other heavy vehicles or aircraft that may pass over it. In general, the larger the diameter of pipe, the deeper it should be buried. A depth of 3 feet is preferable for 8- or 12-inch pipe.

(b) Minimum clearance with underground structures. Buried pipelines often pass close to or cross other buried structures, such as electrical cables, sewage systems, drain tiles, poles, and anchors for poles. Lay the pipeline so other structures will not be damaged during construction or later through settlement, breakage, or movement of the pipeline. In civilian construction, the pipeline usually passes under all other pipelines and similar structures that it crosses. This practice permits work on other utilities without interfering with the pipeline. It also ensures that when the line settles, its weight will not damage other structures. Usually, a clearance of not less than 4 inches (12 inches for metallic structures) is desirable. However, the type of structure will determine the clearance requirements and how to deal with the problem. Such problems could be avoided if, during the planning stage, a route is chosen that avoids interfering structures.

(c) Corrosion prevention. Buried pipe is subject to external corrosion more than pipe exposed to the air. Regular-weight pipe lasts up to about 2 years when buried in most soils. To inhibit corrosion, coat the pipe with corrosion-resistant materials, such as coal-tar enamel or petroleum materials, and apply protective wrappings.

(d) Cathodic protection. External corrosive damage to buried pipe is similar to the chemical generation of electricity in a storage battery. A buried pipeline could contain all of the elements of a battery, which are two materials that have differing electrochemical potentials, connected electrically, and immersed in an electrolyte (the moisture in the ground in which the pipe is buried with its dissolved salts). One material, the anode, is the focus of corrosion.

Cathodic protection is the measures taken to stop the flow of direct electrical currents from the pipeline to and through the soil in which it is buried. This is done by impressing current from external sources through the soil to the pipeline so that the pipe becomes the cathode. Several methods and combinations of methods are used to do this; however, this manual will not address any method, since cathodic protection is not ordinarily installed for military pipelines. Pipelines in captured or allied territory may be equipped with cathodic protective devices and wiring systems. Do not alter or repair these systems without expert advice. Incorrect application of the principles of cathodic protection can do more harm.

(2) Construction Procedures. When burying pipe--

- Dig the trench.
- Assemble the pipe.
- Apply the protective coating.
- Lower the pipe into the trench.
- Back fill the trench.

(a) Precautions in trenching. Before burying a pipeline, a thorough reconnaissance of the route is necessary. The purpose is to locate underground utility and communications lines, drain ditches, irrigation canals and other watercourses, and similar obstacles that will require special treatment. In ditching for a buried line, you can continue the ditch at normal depths across such obstacles when there is no danger of damage to the pipe from accumulated driftwood, washouts, or falling trees. This procedure eliminates the deeper ditch across the bottom of a stream and the pipe bending needed to follow the contour of the deeper part of the ditch. In even terrain, excavate only a length of trench that you can back fill the same day.

(b) Trenching methods. The most efficient tool for digging pipeline trenches is the SEE (Figure 1-4, page 1-8). Pipe is buried in trenches about 20 inches wide with at least 2 feet of cover. If machines are not available, the ditching will have to be done by hand. The trench, when completed, should provide a smooth supporting surface for the pipe. The trench should be deeper between points selected for sags and over bends so the pipeline is as straight as possible. Where this is not possible, the line should be bent with a pipelayer equipped with a bending shoe. Rough spots or irregularities in the bottom of the trench can often be filled in with loose material. The finished trench should be free of clods, rocks, tree roots, and other hard objects.

(c) Assembling pipe. Place the pipe on cribbing alongside the trench for welding assembly.

(d) Coating and wrapping. Remove dirt, paint blisters, and mill scale from the outside of the pipe before applying protective coating. Apply the coating, such as coal-tar or asphalt enamel, with brushes. A second method of applying the coating is with a two-man crew, using the following procedures:

- Pour the coating on top of the pipe and spread it by drawing the pipe back and forth using a belt sling passed under the pipe.
- Wrap a reinforcing mat (fiberglass) around the pipe and imbed it in the coating.

- Apply a protective outer wrap of felt or heavy wrapping paper. As an expedient, you may use burlap or other coarse fabric impregnated with protective material.
- Wait for the pipe to be lifted with belting slings (pipelayer on large pipe sizes) as you reach the cribbing to complete the coating process.

(e) Lowering pipe into the trench. After the protective coating has hardened, pipelayers, equipped with belt-type slings, lower the pipe into the trench. Steel pipe contracts about 0.8 inch per 100 feet for a temperature drop of 100°F. The elasticity of welded pipe offsets this change, and the effect of expansion and contraction of a buried military pipeline is not too significant. The sags placed in the line to follow the contour of the trench must rest on the bottom. Side bends should rest on the bottom of the trench and against the outside wall of the curve.

(f) Filling the trench. If practicable, bury the line during the coolest part of the day while the pipe is contracted. Back fill immediately after lowering in the pipeline so that the pipe or its protective coating will not be damaged. Use only good, loose soil that is free from trash, debris, rocks, or clods as the first layer that you place over the line. Cover the pipe with not less than 4 inches of this type of backfill. If this type is not available along the right-of-way, it should be hauled in from other locations. Use expedient equipment such as angle dozers, bulldozers, or graders to complete the backfill. The crawler-mounted, side-boom backfilled is the most efficient piece of backfilling equipment. When backfilling, be careful not to disturb the coating and wrapping. Do not drop heavy stones on the pipe or allow such stones to roll into the trench against the pipe. Use the following procedures, where applicable:

- Take extra precautions to prevent damage to the pipe and coating in rocky areas. One method is to provide a traveling shield or *lizard* that is pulled ahead of the backfilling machine to absorb the impact of the earth being placed in the trench over the pipe. You can field-fabricate this traveling shield using heavy belting fabric or a piece of shaped metal. Shape it so that the shield will protect the pipe and coating as it is pulled along the ditch.
- Place sandbag dams at intervals in the trench on steep slopes to prevent the uncompacted trench from becoming a sluice for rainwater runoff.
- Make sure the backfill is dry and placed quickly in areas where you encounter considerable groundwater. The pipeline, because of its positive buoyancy, could float and even rise up out of the trench in wet, sloppy backfill.

(3) Testing. You can test for leaky joints before or after lowering the line into the ditch. However, try to test for leaks before backfilling, since leaks are easier to locate.

g. *Bending Pipe.* To change direction or angle in welded pipelines, you can use the fittings shown in Figure B-9, (page B-14). You can make some smaller angle changes by bending the pipe. However, with the type of scrapers presently in military use, the radius of pipe bends must be at least eight times the diameter of the pipe or the scrapers will not pass. (Use more gradual bends when possible.) Pressure loss due to friction increase in the pipe is negligible unless an unusually large number of joints are used. Cold bends and wrinkle bends are the two methods normally used in the field.

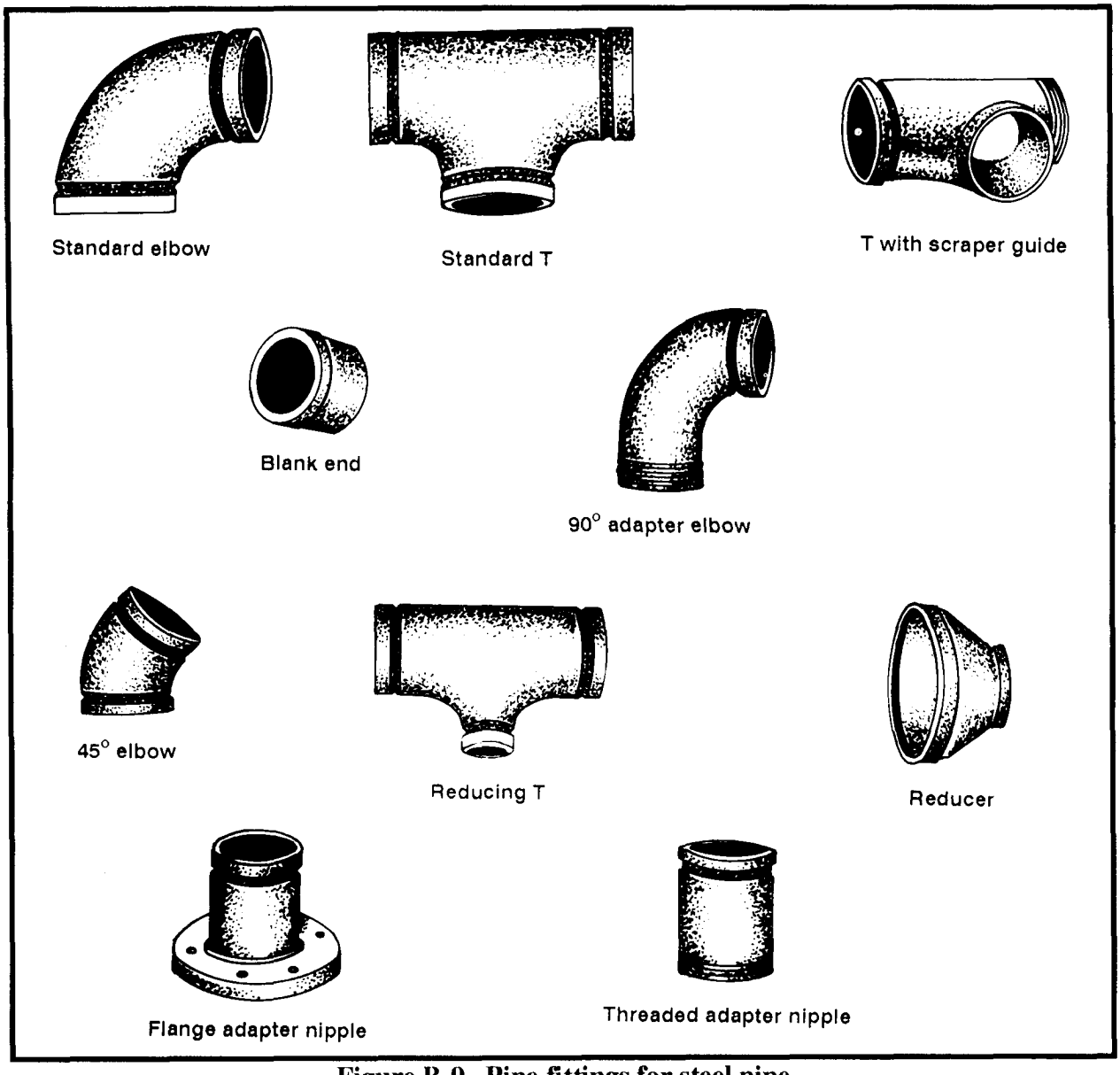


Figure B-9. Pipe fittings for steel pipe

(1) Cold Bends. For cold bends (Figure B-10), the pipe joint is pulled until stressed beyond the yield point of the material, thus causing a permanent set. Do not use this method on thin-walled military tubing. The tubing sections will always buckle before you can attain a slight bend. Hydraulic or mechanical machines provide the simplest method for creating such pipe bends. Use them whenever possible. If these machines are not available, you can bend pipe using any expedient method such as the following:

- Tactical vehicles or simple block and tackle providing bending power.
- Wood cribbing, A-frames, or chassis-mounted shoes fabricated of pipe scraps serving as fulcrums.
- Gin poles or A-frames providing support for vertical bends.

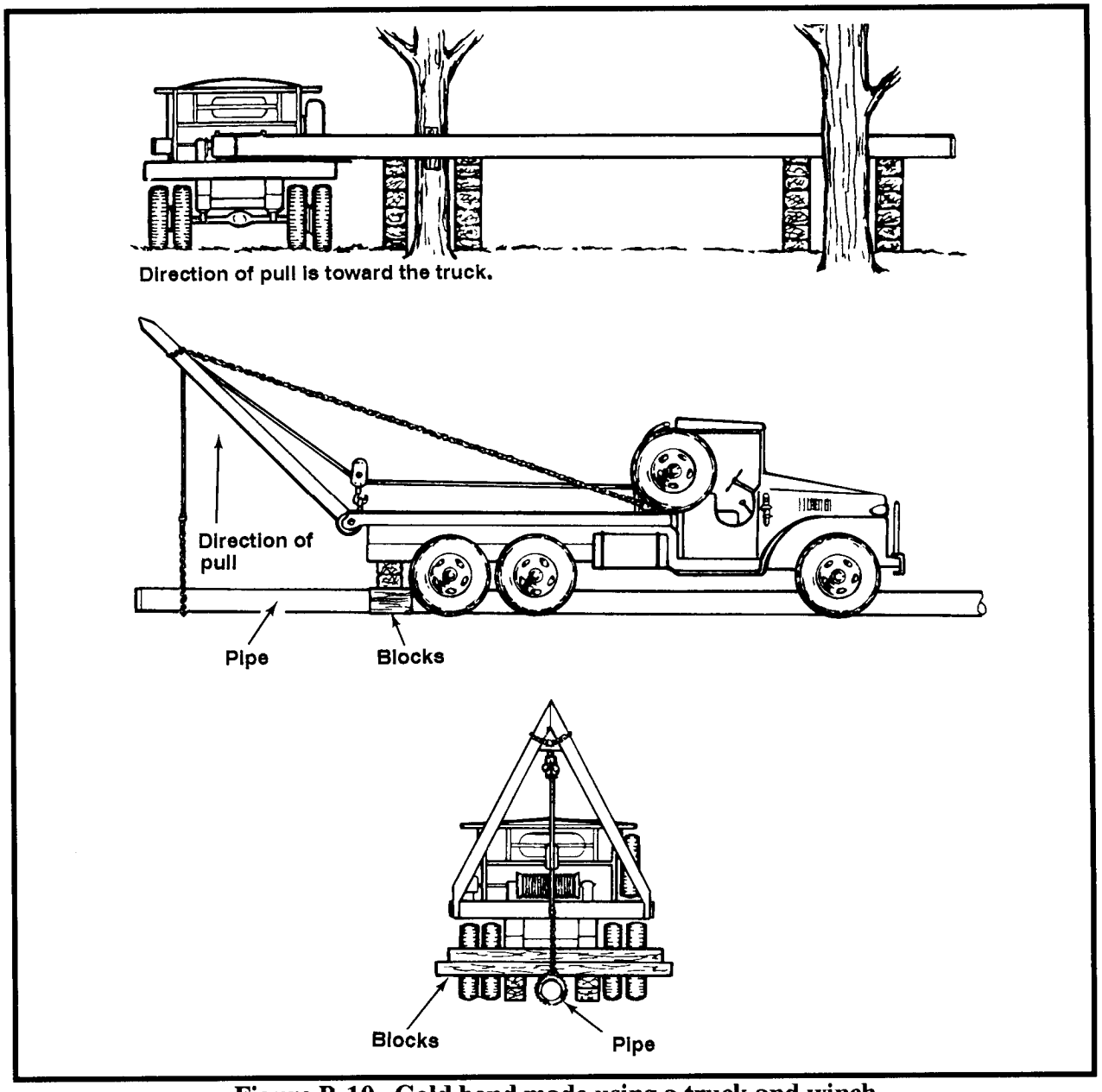


Figure B-10. Cold bend made using a truck and winch

Use the following equation to determine the pipe lengths for cold bends:

$L = RD\ (0.017) + T$

where--

L = *length of bend, in inches.*
R = *radius of bend (to centerline of pipe), not less than 8 times the nominal pipe diameter, in inches.*
D = *number of degrees in the bend.*
T = *total length of tangents on each end of bend, in inches.*

Example

Find the minimum length of 8-inch pipe required to make a 90-degree bend having l-foot tangents on each end.

R = 64 inches (8 inches x 8)
D = 90 degrees
T = 24 inches (2 x 12 inches)
L = 121.92 or 122 inches (64 x 90 x 0.017+24= 97.9+ 24)

(2) Wrinkle Bends (Figure B-l1). Use an acetylene torch to heat the pipe (not tubing) to produce an area of relative weakness. If done correctly, the bent portion of the pipe will have an outwardly projecting wrinkle. The method requires a skilled welder and a large amount of time and materials. (Wrinkle bending has become less popular because of specialized, reliable, cold-bending machines.) Use the following procedures for this method:

(a) Mount the pipe so that its entire circumference is accessible to the welder. Do this by laying the pipe on the ground and digging a hole around the area to be heated or by supporting it on cribbing or on a field-fabricated metal frame.

(b) Construct a fulcrum using pipe sections driven into the ground for horizontal bending, or use a field-fabricated shoe welded to a truck chassis for vertical bends. You could conceivably use a section of larger diameter pipe, properly staked or weighted, as a fulcrum.

(c) Use items such as heavy-duty, manual screw jacks; block and tackle; and power winches for an easily controllable bending force.

(d) Construct a gin pole or A-frame for supporting pipe on vertical bends or cribbing for horizontal bends.

(e) Heat a narrow band of the pipe (about two-thirds to three-quarters around the pipe's circumference) with a torch to a bright cherry-red color close to the desired bend.

(f) Bend the pipe inward on the heated portion to form a wrinkle in the pipe wall. Limit the bend to no more than 5 degrees.

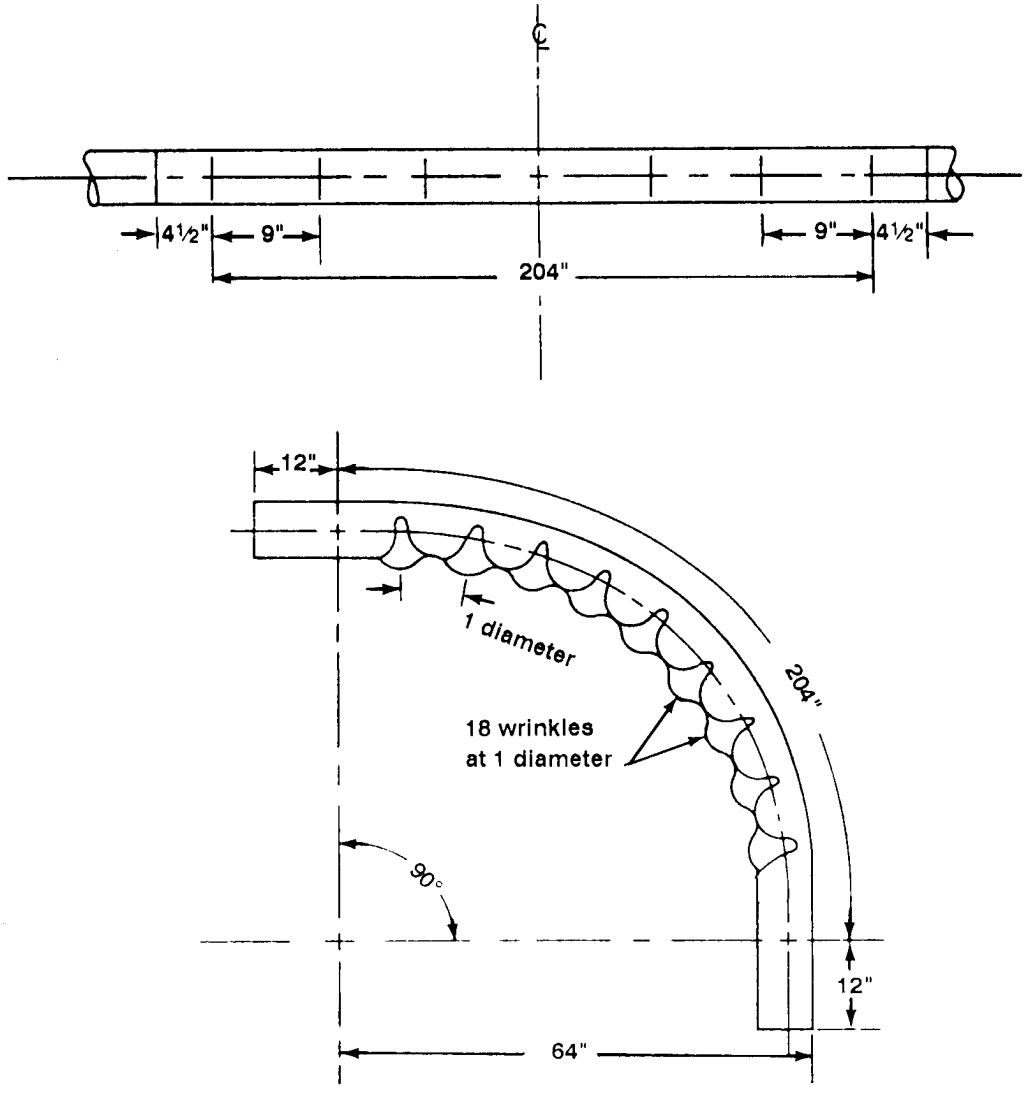
(g) Space each successive bend one pipe diameter apart.

To determine length of pipe required for winkle-bending degree of bend, use the following equation:

$$L = \frac{(\textit{degree of bend})}{5^\circ} - 1 \times \textit{nominal pipe diameter} + T$$

where--

L = length of pipe required, in inches.
T = total length of tangents on each end of bend, in inches.



Heat tubing to cherry red about 2/3 or 3/4 way around tubing. Heated band should taper from ½" wide at points to 1" wide at center, spaced 1 diameter apart for 6" pipe. Heated band for 8" tubing should be 1/32" 3/32" 1/16"1¼" wide at center, spaced 1 diameter apart. Heated band for 12" tubing should be 1½" wide at center, spaced 1 diameter apart.

Figure B-11. Wrinkle bending

Example

Find the length of 8-inch pipe required to make a 90-degree bend having l-foot tangents on each end of the bend.

T = 24 inches (2 x 12)
L = 160 inches ((90/5 - 1) x 8 + 24= 17 x 8 + 24= 136 + 24)

(3) Underwater Crossings. Use a 2-foot minimum cover at all underwater crossings, regardless of stream-bed conditions. Two feet is sufficient where crossings are made in solid rock. However, increase the cover as the streambed changes from rock to sand. (A 6-foot cover is necessary in a sandy, shallow river.) Measure the cover below the lowest point in the streambed.

Many rivers carry more water underground in their broad, sandy valleys than is carried as surface water. These rivers are likely to scour badly during flood stage. If this condition exists, lay the line flat across the valley from the fixed low point so that future channel changes and scouring will not affect the crossing. A stream with low banks in a wide, sandy valley will be subject to overflow and scour across the entire valley. If this condition exists, place the line below scour depth all the way across the area subject to high water. If possible, place the crossing in a long, straight reach of the stream, as the banks are less likely to cut and expose the line.

Crossings at bends or narrows will be subject to stress or damage from floods, water velocity, and scouring of the streambed. Do not provide an upstream or downstream bow in the line. It is difficult to pull an accurate bow in a pipeline. Unless you properly bury the pipeline, it might become a swinging line. Driftwood lodging against a swinging line may exert a force great enough to pull the line apart. Bury the line deep enough and far back from the water's edge so that fast flood waters will not uncover and damage the line.

Examine the crossing site closely to determine the height of previous flood waters. The pipeline placed in the riverbed should be flat. If practicable, excavate the banks so that you will not need sags or overbends. Place block valves above the highest watermark on each side of the river. As soon as possible, construct an alternate crossing several hundred yards upstream or downstream to provide uninterrupted flow if the major crossing is damaged (Figure B-12). Connect this alternate crossing line to the main crossing at a point well back from any possible flood zone so that the block valves can be located and safely reached if necessary.

(a) Preparing the bottom (ditching). The method of excavating the ditch for a river crossing will depend on soil conditions and available equipment. Sand may be wet-excavated by means of a dredge or dragline, or it may be dewatered with well points and dry-excavated with a dragline. Occasionally, you can use a sand pump to remove sand or silt from underneath a line to lower it into place or to prepare the ditch just ahead of the line as it is launched. You can remove rock (and mud) by drilling and shooting through water, if necessary.

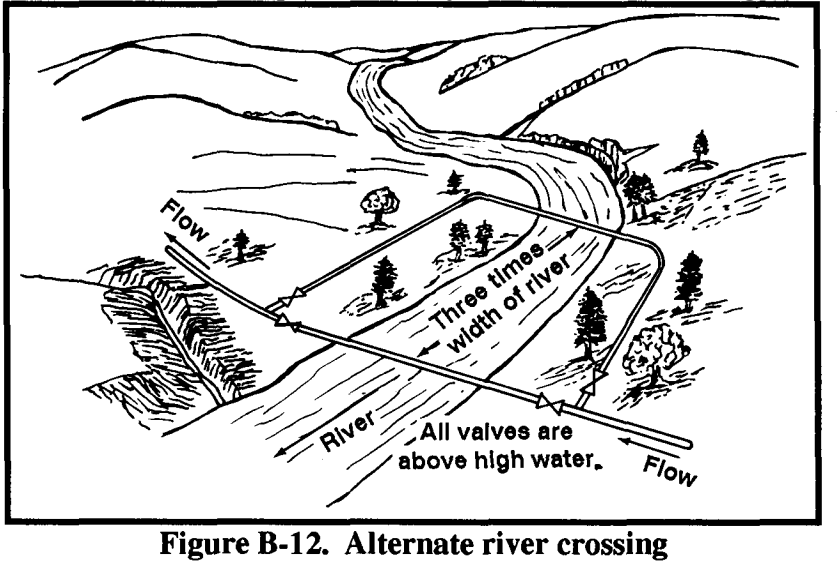


Figure B-12. Alternate river crossing

(b) Assembly and launching. Submerged pipeline river crossings will be of welded construction and only heavy weight submarine line pipe. Assembly and installation of

major crossings are the same as for submarine pipelines except that the triple-drum (pulling) winch and the holdback winch would be on opposite sides of the river. Place the pulling winch on the far side and the holdback winch on the near side. Use tractor or truck winches for smaller crossings. As soon as the pipeline has been pulled into place, pump it full of water to displace the air in the pipe and increase the line's in-place weight.

(c) Backfill. Pay particular attention to the backfill on the banks of streams. A soft backfill in a wide right-of-way cut is likely to slide into the stream during a flood or to be carried away by the current. In either case, future floods will erode the bank and expose the line. Firmly tamp the backfill and reinforce it with sacked earth, rip-rap, or other similar materials, if necessary. Backfill the streambed ditch with crushed rock, if practicable. Backfill the streambed ditch carefully if you use earth. Use a clamshell to lower the earth to the bottom of the ditch; place the backfill directly on top of the pipeline. Do this operation quickly to minimize mixing the earth and water. Since mud has a higher specific gravity than water, the line is buoyed up more than it is by water. The drier the backfill, the better.

h. *Welding Repairs.* Welding is used to make temporary and permanent repairs on welded pipelines. Welding can be extremely dangerous. It should be done only in an emergency by a skilled welder. The commanding officer of the using organization must approve any welding operation. The welder should use only electric arc welding, be supervised, and weld according to the guidelines in TM 9-237. The safety officer should issue a permit to weld; the permit should be posted in the welding area. Once a welder has permission to weld, he should--

- Move fire-fighting equipment into the area.
- Wear clothing and shoes that protect him from the fuel and the welding operations.
- Use an explosimeter to find out if fuel vapors are in the welding area. The readings must be in the safe zone before welding.
- Use the right size and type of electrodes and not worn electrodes.
- Pack the line with moving fuel to displace the vapors and to carry heat away from the weld.
- Keep in constant contact with the pumping-station operator. He must stop welding if pumping operations stop or if pressure in the line drops.

i. *Pipeline Painting.* Paint coupled steel pipeline with enamel to prevent rusting and to reflect heat. (The first coat is applied at the factory.) Paint identification markings on pipe sections after putting the pipe into operation. Pipelines are checked often for chipped and flaking paint to make sure that the protective coating and the markings do not wear away.

(1) Protective Coating. To spot paint the protecting coating--

- Use a wire brush and paint scraper to remove flaking paint and rust.
- Sand the surface down to the bare metal.
- Wipe the surface clean.
- Paint with red lead primer (DOD-P-17545). Let the primer dry.

- Paint the primed areas with rust-inhibiting, semigloss enamel (Federal Specifications TT-E-485F). Use the natural color to reflect heat unless the pipeline has been painted with camouflage colors.

(2) Markings. Check the markings on the pipeline and paint them if they cannot be read easily. The markings (Figure B-13), which are painted on the line near valves, should conform to the guidelines in AR 385-80 and MIL-STD-161. Some marking guidelines are--

- Bands of yellow paint symbolize caution. Yellow bands are used to warn of the presence of flammable materials.
- The number of bands that appear around a pipeline identify the fuel that is pumped through the pipeline.

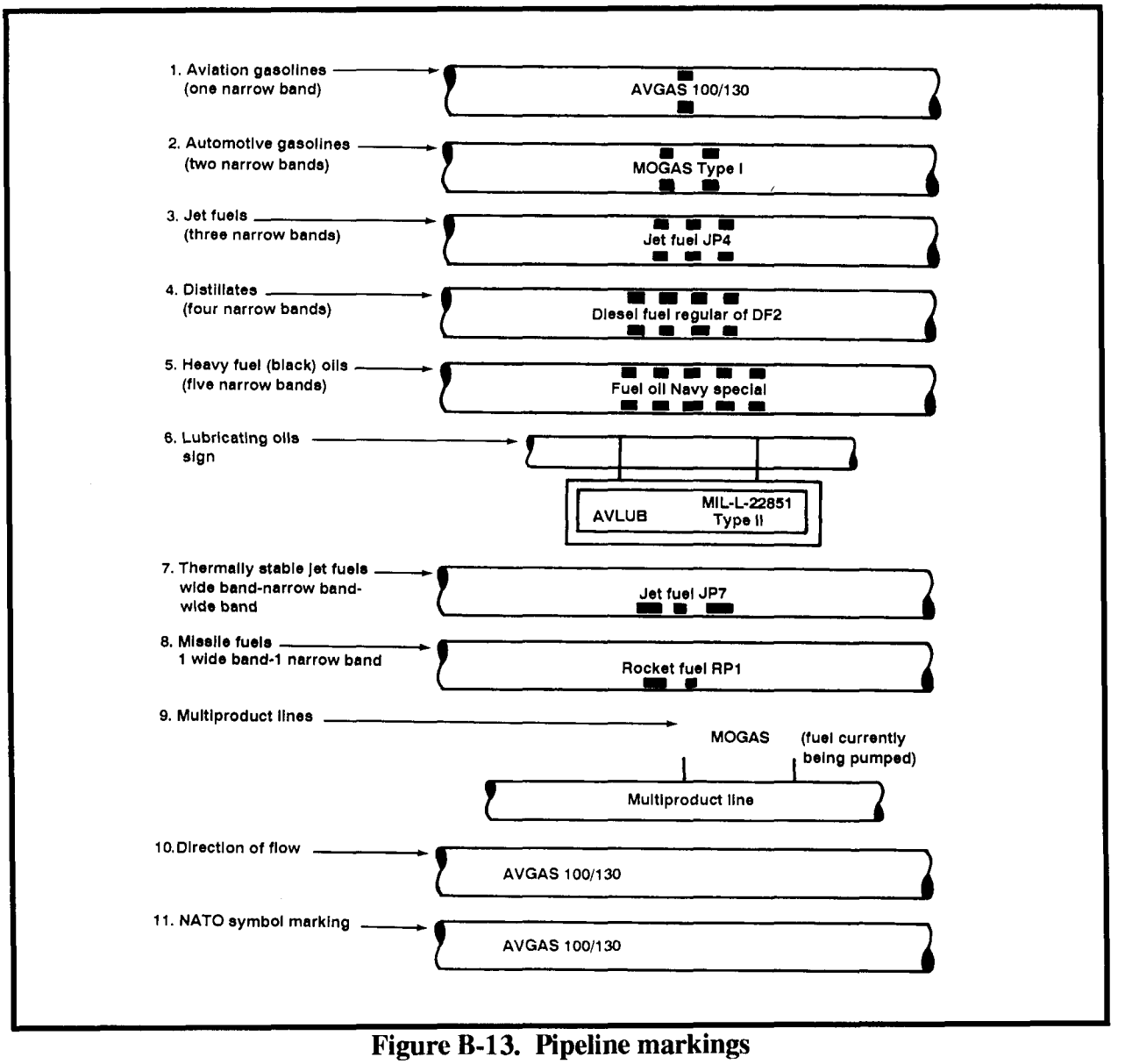


Figure B-13. Pipeline markings

- A sign with a black background and white letters on each pipeline that identifies the fuel.
- A yellow arrow shows the direction in which the fuel is flowing in the pipeline.

B-5. Welded Pipelines. Welded pipelines should be buried. However, if a leak occurs, it could go unnoticed until it is large enough to affect the fuel pressure in the pipeline. A sudden drop in pressure from one pumping station to the next could mean a leak in that section of the line. Comparing the amount of fuel pumped through meters at various locations could narrow down the area. A drop in throughput from one meter to the next indicates a leak between the meters. When the general area of the leak is determined, the line is laid bare so it can be repaired. Remove the dirt around the pipeline until you find the exact location of the leak. Dig out the area around the leak completely, allowing for working room and a clear escape route from the trench.

a. *Temporary Repairs.* Use clamps or weld temporary repairs. There are three types of temporary repairs on pipe sections you can do by welding (Figure B-14). The type of welding repair will depend on the size of the damaged area.

(1) Small Pits. Small pits in the outside wall of a pipe section are spot-welded so that the pits are flush with the outside of a pipe. This repair is called pit patching. Use this method only when the pipe is in good condition or if there are a few rust spots. When making a rust repair--

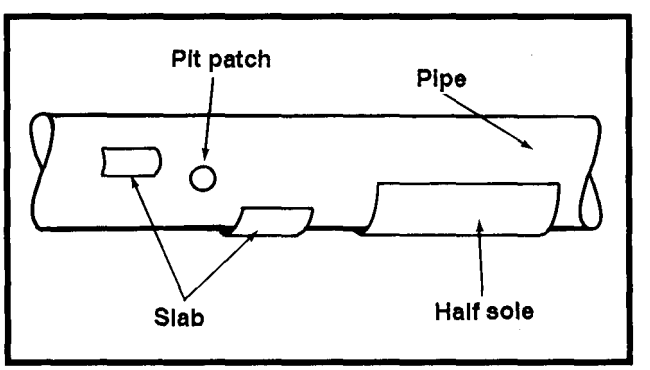


Figure B-14. Temporary welded repairs

- Clean the rusted area down to bare metal.
- Use a pit gauge to measure the pits.
- Fill in the pits that measure less than one half the thickness of the pipe.
- Maintain flow in the pipeline to carry away the heat.

(2) Areas Less Than One Half of the Pipe. You can repair rust areas that are on less than one half of the pipe circumference by welding precut pieces of pipe over the damaged areas. The patches may vary in size from small slabs to half soles or half wraps that cover half of the pipe. When making this repair--

- Cut a patch from a pipe section slightly larger in diameter than the damaged one.
- Reshape the patch so that it fits snugly against the pipe.
- Clean the rusted area down to the bare metal.
- Hold the patch in place with steel leak clamps (Figure B- 15, page B-22).
- Weld the patch in place on all sides and remove the clamps.
- Maintain flow in the pipeline to carry away the heat.

(3) Areas More Than One Half of the Pipe. You can repair pipe that is rusted in large areas on the top and on the bottom by surrounding the damaged line with a casing. To make this repair--

- Cut a casing, from new pipe, slightly larger in diameter than the damaged pipe.
- Cut the casing in half along the entire length.
- Wrap the two halves around the damaged pipe.
- Hold the pieces in place with clamps and weld them together.
- Run welding bead around the casing at each end.
- Maintain flow in the pipeline to carry away the heat.

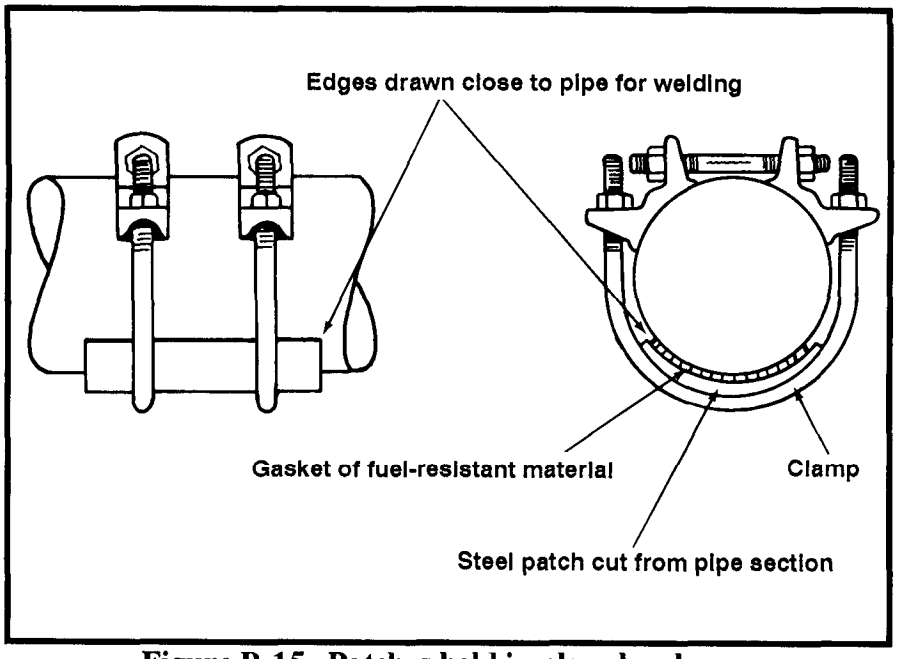


Figure B-15. Patches held in place by clamps

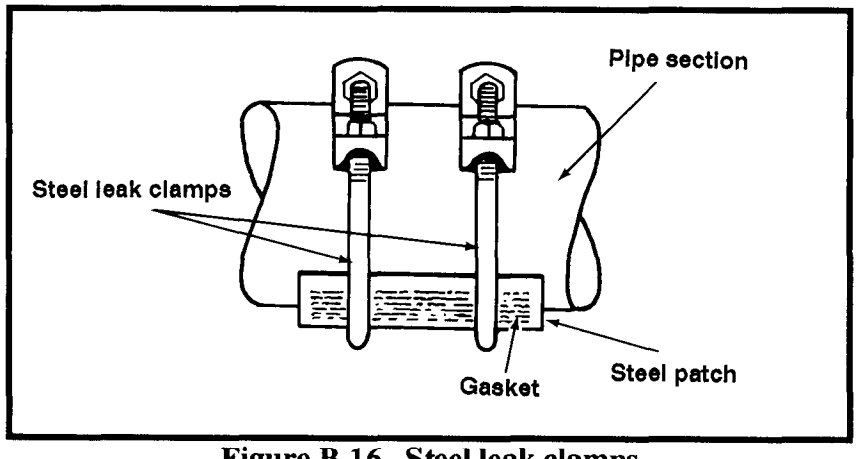


Figure B-16. Steel leak clamps

(4) Clamp Repairs. You can temporarily repair small pit leaks with steel leak clamps (Figure B-16). Using these clamps is a stopgap measure. The repaired pipe should be replaced as soon as possible. To mount a steel leak clamp--

- Cover the leak with a cone-shaped or a flat gasket. Make sure the gasket is made of fuel-resistant material.
- Cut a steel patch to cover the gasket. Curve the patch to match the curve of the pipeline.
- Hold the gasket and the steel patch in place and cover them with steel leak clamps.
- Put the bolts in the clamp, attach the nuts, and tighten the nuts.

b. *Permanent Repairs.* Permanent welding repairs are made by removing damaged pipe and welding new pipe in place. The temporary measures described above should be replaced with permanently welded pipe as soon as possible. Permanent welding repairs are made with and without the use of a bypass. The method used depends on whether or not the repair is an emergency.

(1) Emergency Repairs. If a large leak occurs that cannot be repaired with clamps, pumping operations are stopped and the commanding officer and the safety officer are notified. The leaking section is then replaced as quickly as possible without taking the time to construct a bypass. Such an emergency pipe change can be dangerous because of escaping fuel and fuel vapors. You must follow all safety rules. Once you locate the leak--

(a) Move fire-fighting equipment into the area.

(b) Wear proper clothing and shoes for protection from spills and welding operations.

(c) Close gate valves on each side of the leak to limit the amount of fuel flowing to the leak.

(d) Move anything that could cause a spark out of the area.

(e) Drain any fuel still in the damaged section of pipe into drums or tank vehicles. Use a suction pump to remove fuel that may have collected in the trench.

(f) Cover spilled fuel and fuel-soaked ground with fire-retarding foam.

(g) Let vapors be carried away or dispersed in the air.

(e) Use an explosimeter to find out if there are fuel vapors left in the area of the leak. Check inside the pipe. Displace fuel vapors with carbon dioxide or nitrogen (both are available in fire-fighting equipment). Make repairs only when the readings on the explosimeter are in the safe zone.

(f) Dig out a trench so personnel can work around and under the section of pipe. Make sure there is an escape route.

(g) Cut out the section of damaged pipe with mechanical cutters and move the damaged pipe out of the way.

(h) Swab out the pipe ends and clean the pipe end bevels with a wire brush and file.

(i) Move the new section of pipe into position and align it with the old pipe.

(j) Hold the new section in place with clamps and weld the sections together. (Remember that only skilled welders may do the welding.)

(k) Open the gate valves slowly to let pressure and fuel back into line.

(1) Start pumping operations.

(m) Purge the entrained air from the pipeline.

(n) Check for leaks.

(o) Coat bare areas of pipe with coal-tar enamel. Wrap the pipe with a layer of felt.

(p) Bury the pipeline.

(2) Nonemergency Repairs. If a small leak occurs, stop the leak with a steel leak clamp until the pipe can be replaced. Spot-welded and patched pipe should also be replaced as soon as possible. Get permission to weld from the commanding officer of the using organization and a permit to weld

from the safety officer. Since this is not an emergency repair, you can build a bypass line, which will carry fuel around the repair area. Using a bypass line means that pumping operations can go on while you replace the damaged section. Be careful so that fuel vapors will not ignite. Wear proper clothing and shoes for protection from fuel spills and welding operations. Move fire-fighting equipment into the area and post the welding permit. To replace a section of welded pipe, using a bypass line--

(a) Dig out the area around the pipeline and provide space for the bypass line.

(b) Make sure the line is packed with fuel to displace vapors and to carry heat away from the weld. Keep in contact with the pumping-station operator to make sure that pressure in line does not drop.

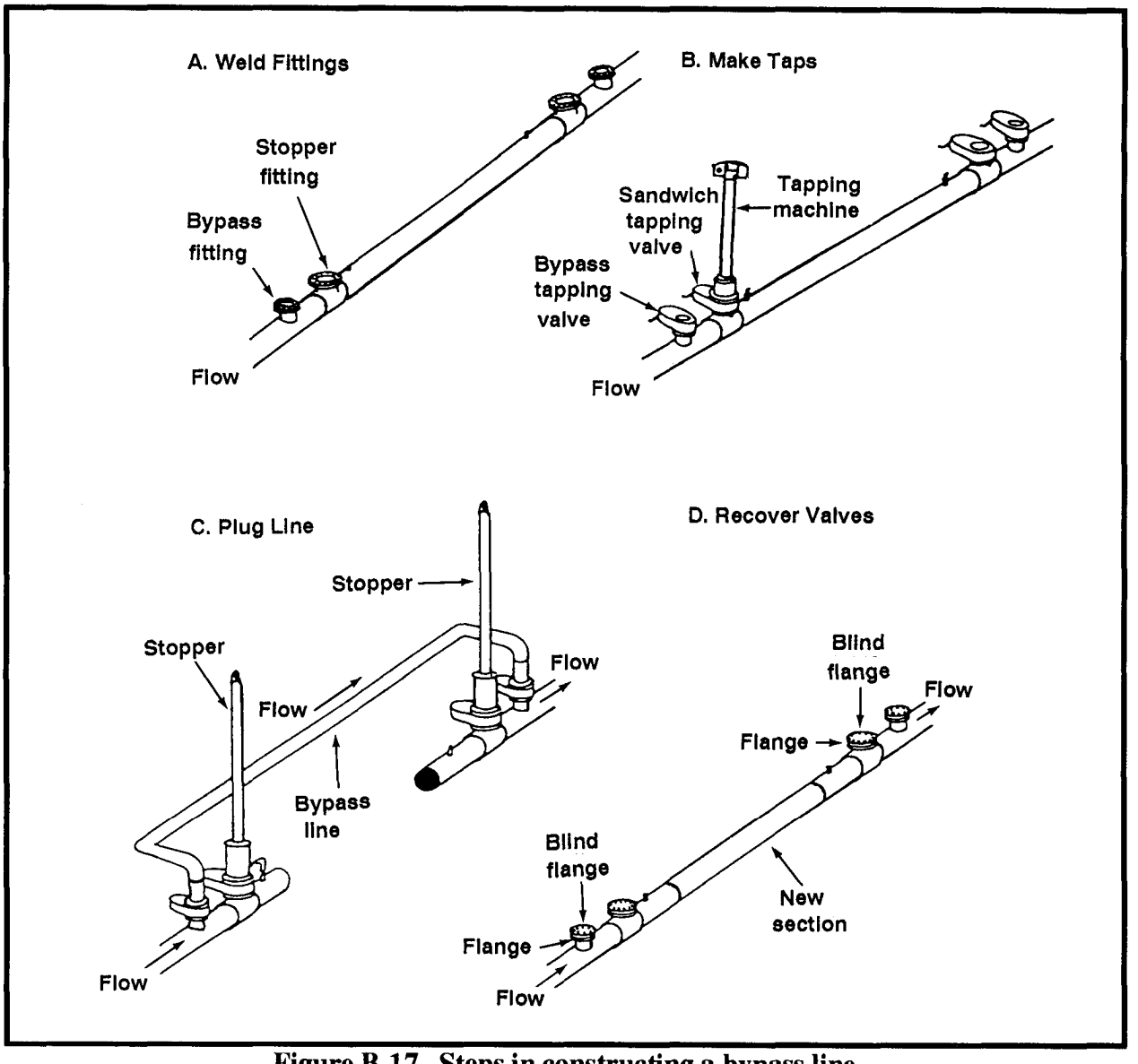


Figure B-17. Steps in constructing a bypass line

(c) Weld a bypass fitting and a stopper fitting on each side of the pipe section you are replacing (Figure B-17, A). (Remember, only skilled welders may weld.)

(d) Bolt a bypass-tapping valve on each bypass-fitting and a sandwich-tapping valve on each stopper fitting.

(e) Attach a tapping machine to the bypass valves, tap through the valves, close the valves, and remove the tapping machine.

(f) Construct a bypass line and attach it to the pipeline at the bypass-tapping valves.

(g) Use the tapping machine to cut into pipe at the sandwich-tapping valve (Figure B- 17, B).

(h) Put the stoppers in place and plug off the flow in the main line. This forces the fuel to flow into the bypass line (Figure B-17, C, and Figure B-18).

(i) Tap or break the line in the repair section and drain the fuel into drums.

(j) Cut out the damaged section with mechanical cutters and move it out of the way.

(k) Allow time for the fuel vapors to be carried away or dispersed in air.

(l) Swab out the ends of the old section of pipe.

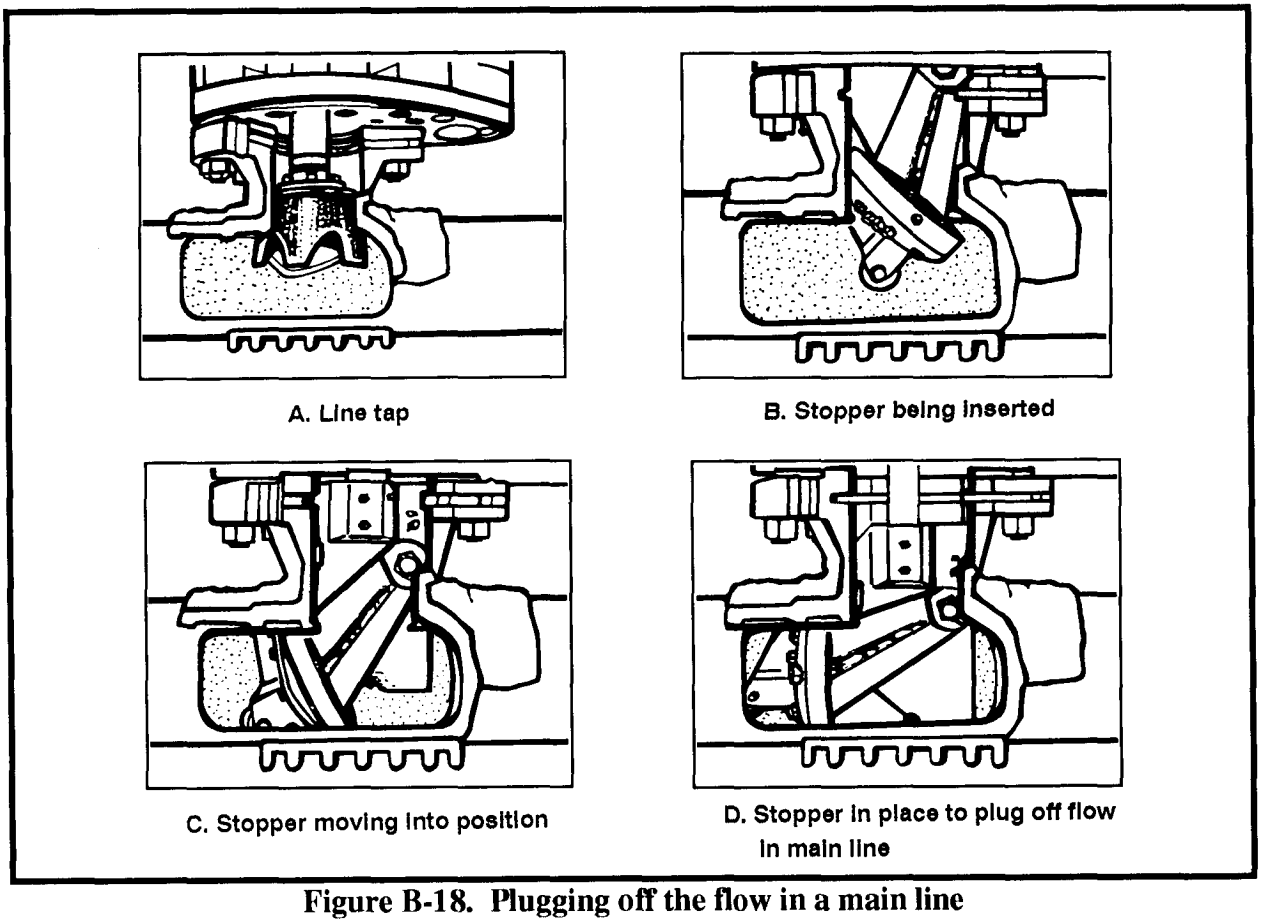


Figure B-18. Plugging off the flow in a main line

(m) Use an explosimeter to find out if fuel vapors are left in the repair area. Do not weld until the readings are in the safe zone.

(n) Move the new section of pipe into position and align it with the old pipe.

(o) Clean the pipe-end bevels with a wire brush and file.

(p) Hold the new section in place with clamps and weld the pipe sections together.

(q) Stop pumping operations to reduce pressure in the line to zero.

(r) Take out the stoppers and remove the sandwich-tapping valves, the bypass line, and the bypass-tapping valve.

(s) Bolt blind flanges in place to cover the bypass and stopper fittings (Figure B-17, C and D).

(t) Start pumping operations.

(u) Purge the entrained air from the pipeline.

(v) Check for leaks.

(w) Coat bare areas of pipe with coal-tar enamel. Wrap the pipe with layer of fiberglass and a layer of felt.

(x) Bury the pipe and fill in any area dug out for the bypass.

(3) Clamp Repairs. There are two kinds of clamps you can use to repair minor damage to a pipeline permanently. Both of the clamps are made of stainless steel and require the use of fuel-resistant gaskets.

(a) Band repair clamps. Use this clamp (Figure B-19) to repair a small leak. To mount--

- Cover the leak with a fuel-resistant gasket.
- Wrap the clamp around the pipeline, taking care to cover the gasket.
- Put the bolt in the clamp, place a nut on the bolt, and tighten the nut.

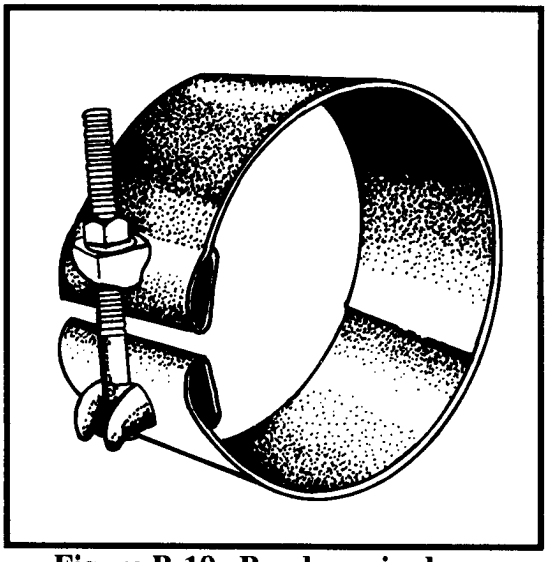


Figure B-19. Band repair clamp

(b) All-around pipe repair clamp. Use this clamp (Figure B-20) to repair pitted areas and breaks that run completely around the pipeline. To mount the clamp--

- Cover the rusted area or break with a fuel-resistant gasket. You may have to use gasket material to cut a gasket large enough to fit.
- Wrap the clamp around the pipe, covering the gasket.
- Put the bolts in the clamp, place the nuts on bobs, and tighten the nuts.

B-6. Hose Lines. Patching equipment is provided for repairing seeping or spraying leaks that may develop through the wall of the hose during testing and use (Figure B-21). While the hose is still under operating pressure, cover the leak and an area from 4 to 6 inches on each side with one spiral wrap of 2-inch-wide neoprene rubber tape and two spiral wraps of 2-inch polyvinyl tape. Apply the tape wraps with as much tension as you can.

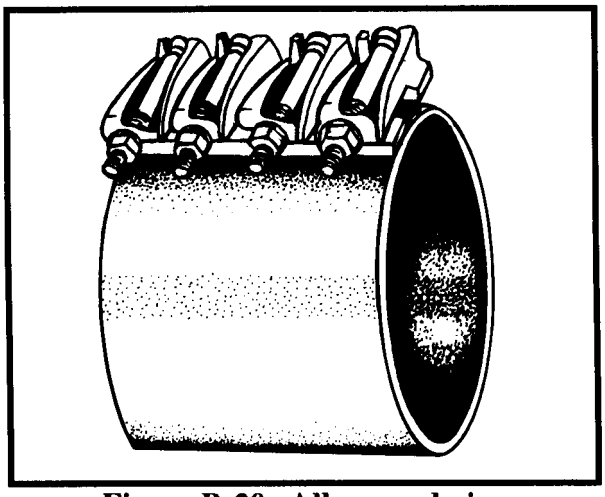


Figure B-20. All-around pipe

If a hose develops excessive leakage from a split or puncture, repair it by cutting out the defective area and rejoining the cut ends with two coupling sleeves and a coupling. Install hose clamps (included in the hose-repair kit) on each side of the leak far enough to reach an undamaged area (Figure B-22, page B-28). Use rubber cement as a lubricant so you can insert the sleeves into the hose easier. Using a special banding tool, wrap stainless steel bands around the exterior of the hose end and over the sleeve to firmly join the hose to the sleeve. You can use hand tools (included in the kit) to help install the sleeves. After you finish attaching the repaired sleeves, bring together the grooved ends of the sleeves and connect them with lightweight, groove-type couplings.

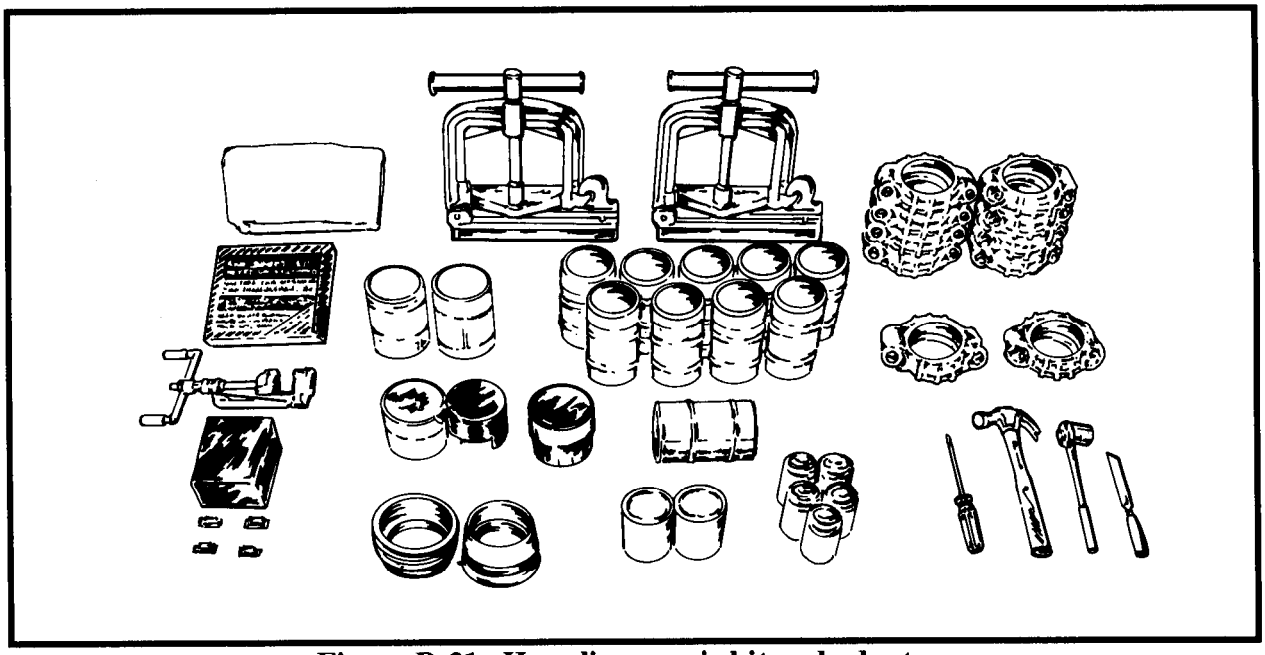


Figure B-21. Hose-line repair kit and adapters

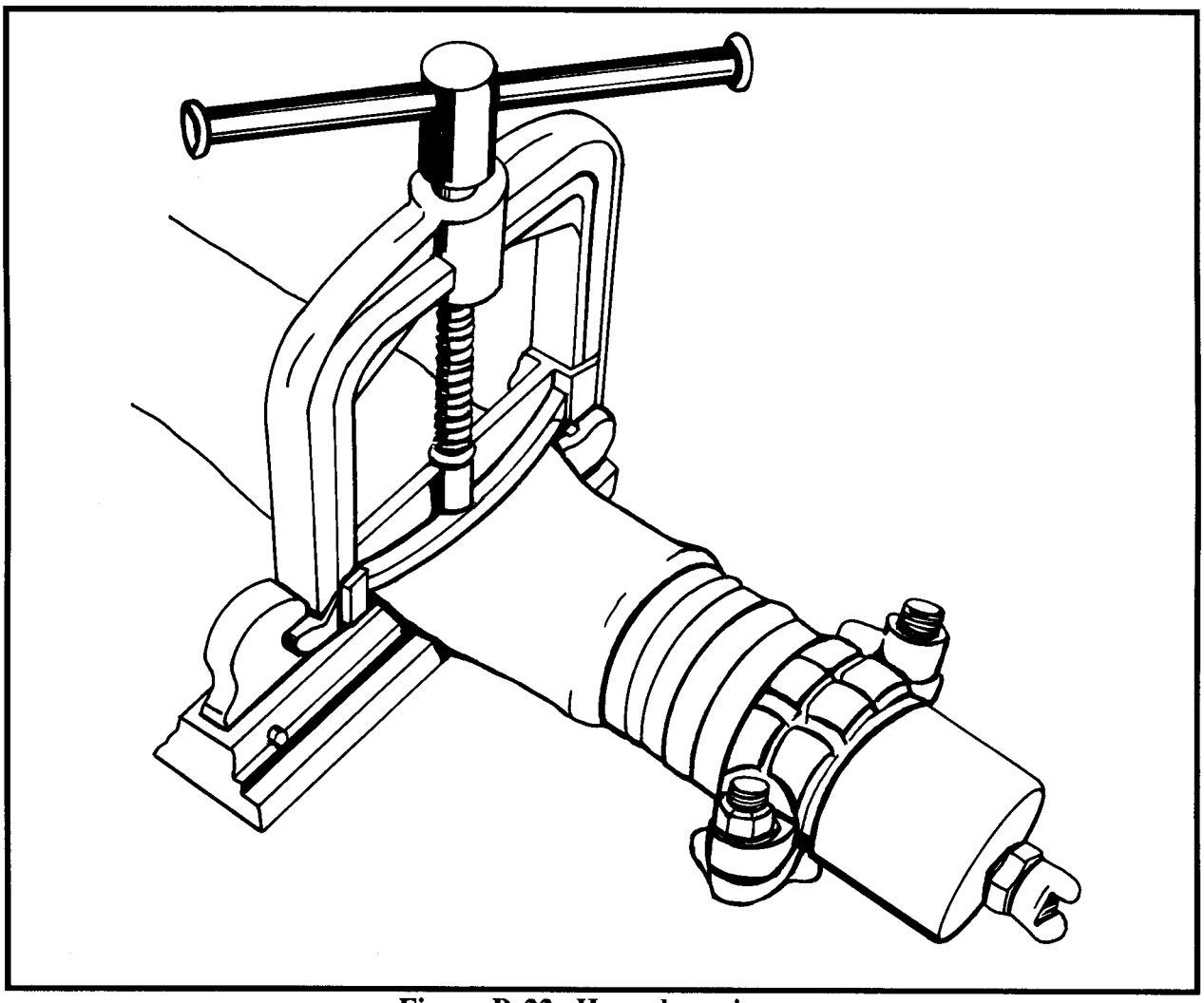


Figure B-22. Hose clamp in use

Appendix C. Pump Curves and Design Charts

This appendix contains the pump curves, correction factors, and pipeline design charts necessary during pipeline construction operations.

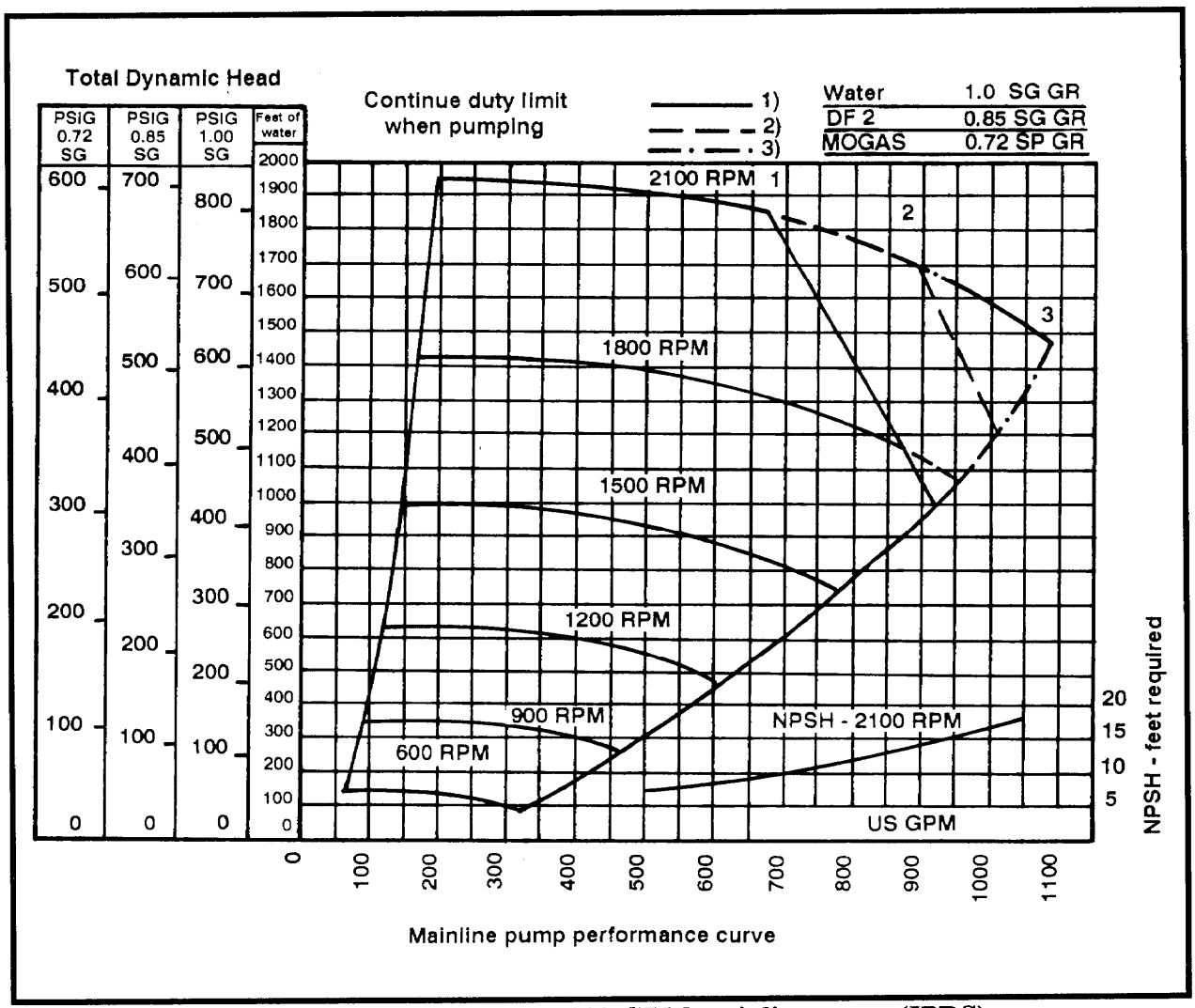


Figure C-1 6-inch, 3-stage, 800-GPM mainline pump (IPDS)

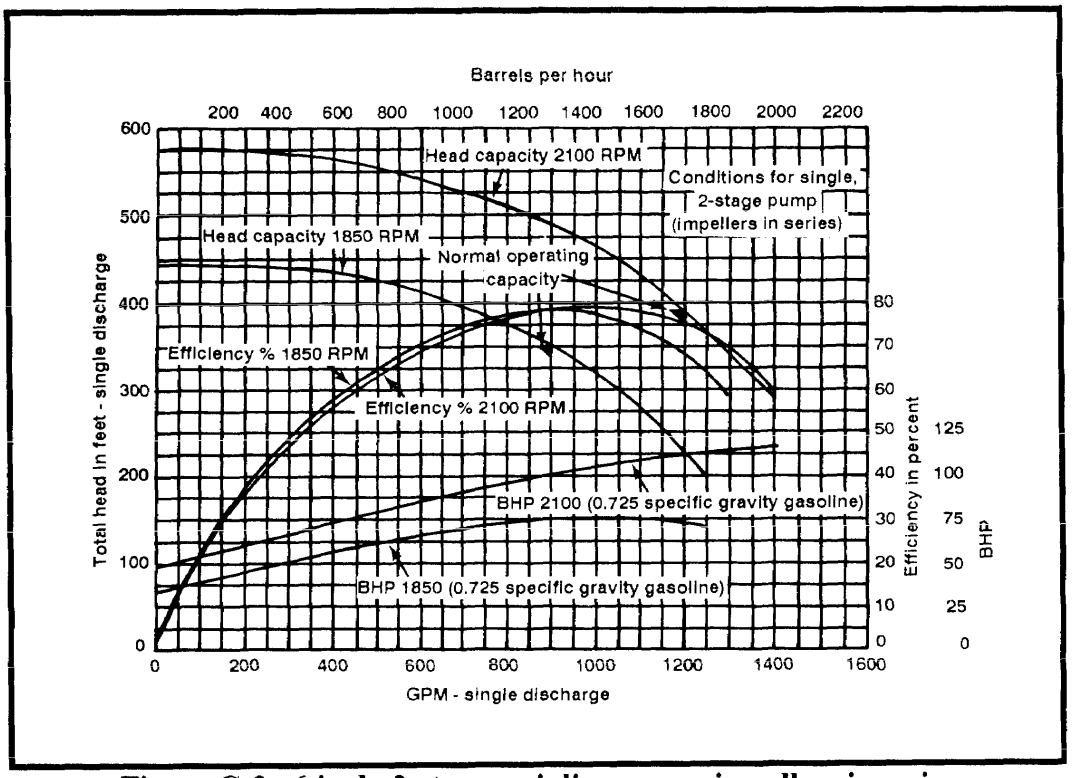


Figure C-2. 6-inch, 2-stage mainline pump, impellers in series

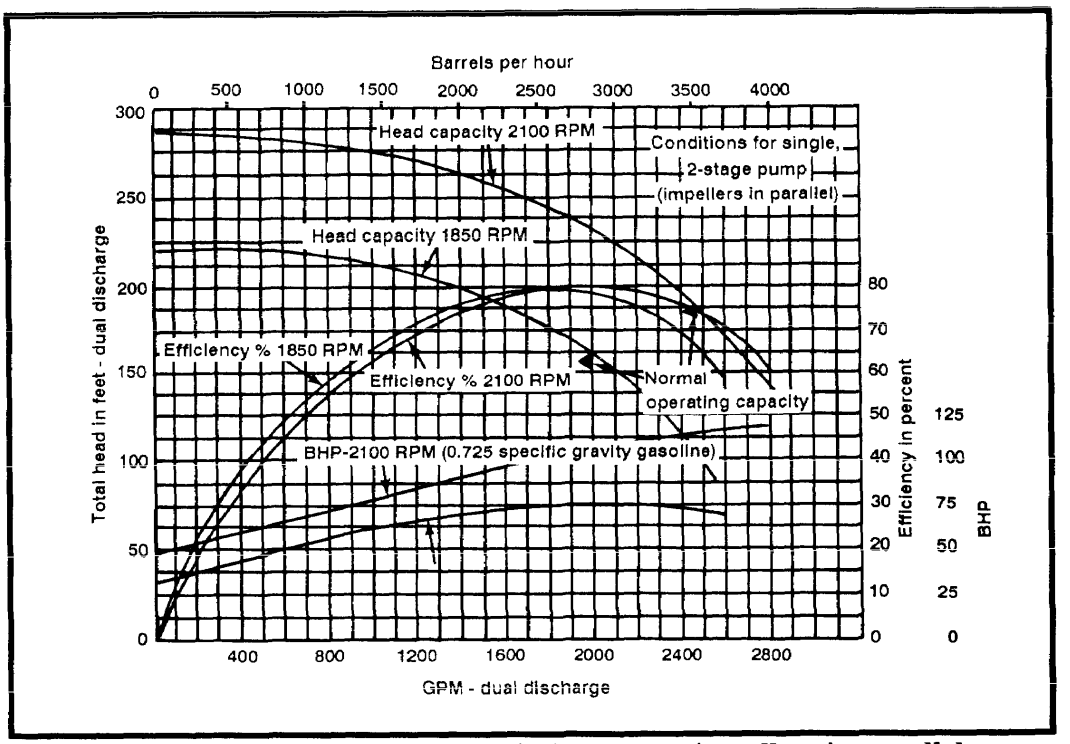
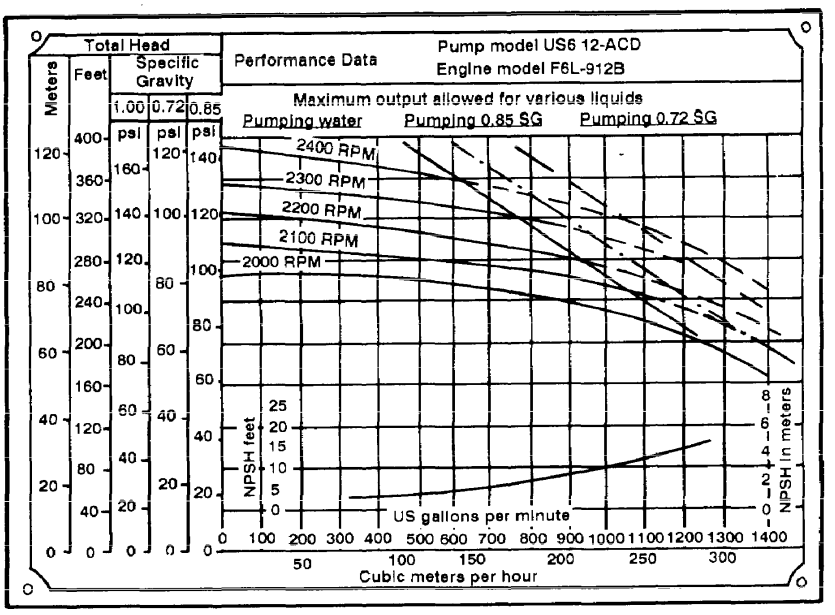


Figure C-3. 6-inch, 2-stage mainline pump, impellers in parallel



Performance Curve

600-GPM hose-line pump
Peabody Barnes Model US612-ACD-1

1250 GPM flood-and-transfer pump
Peabody Barnes Model US612-ACD

Figure C-4. 6-inch, single-stage, 600- and 1,250-GPM self-priming pump (IPDS)

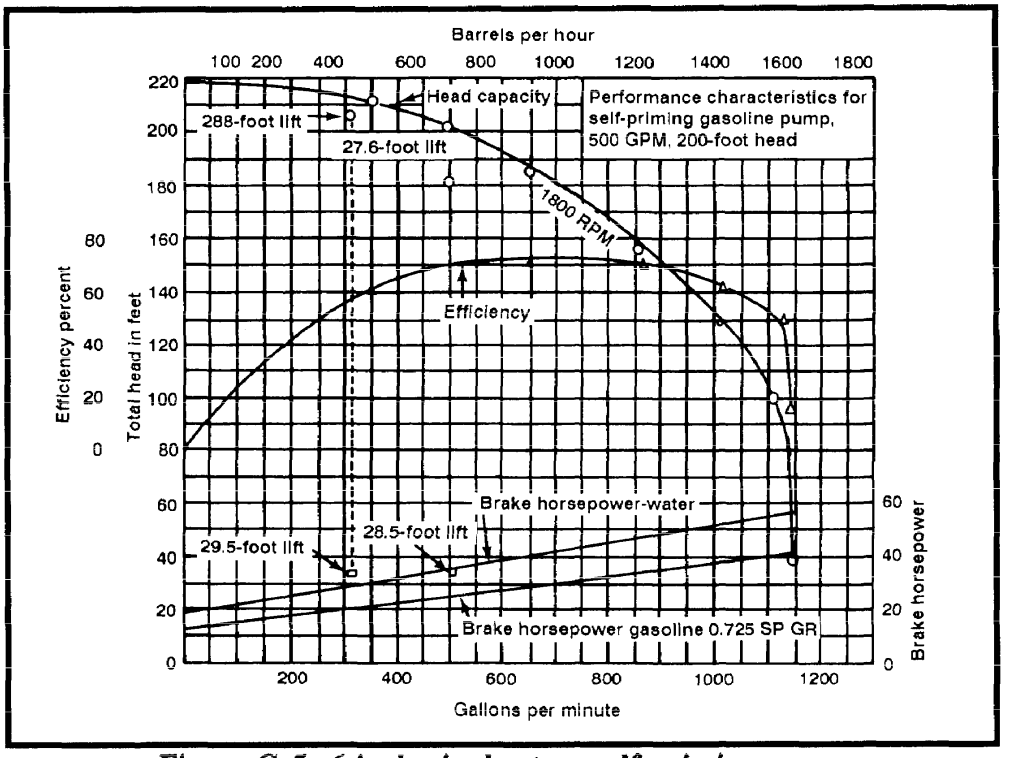


Figure C-5. 6-inch, single-stage self-priming pump

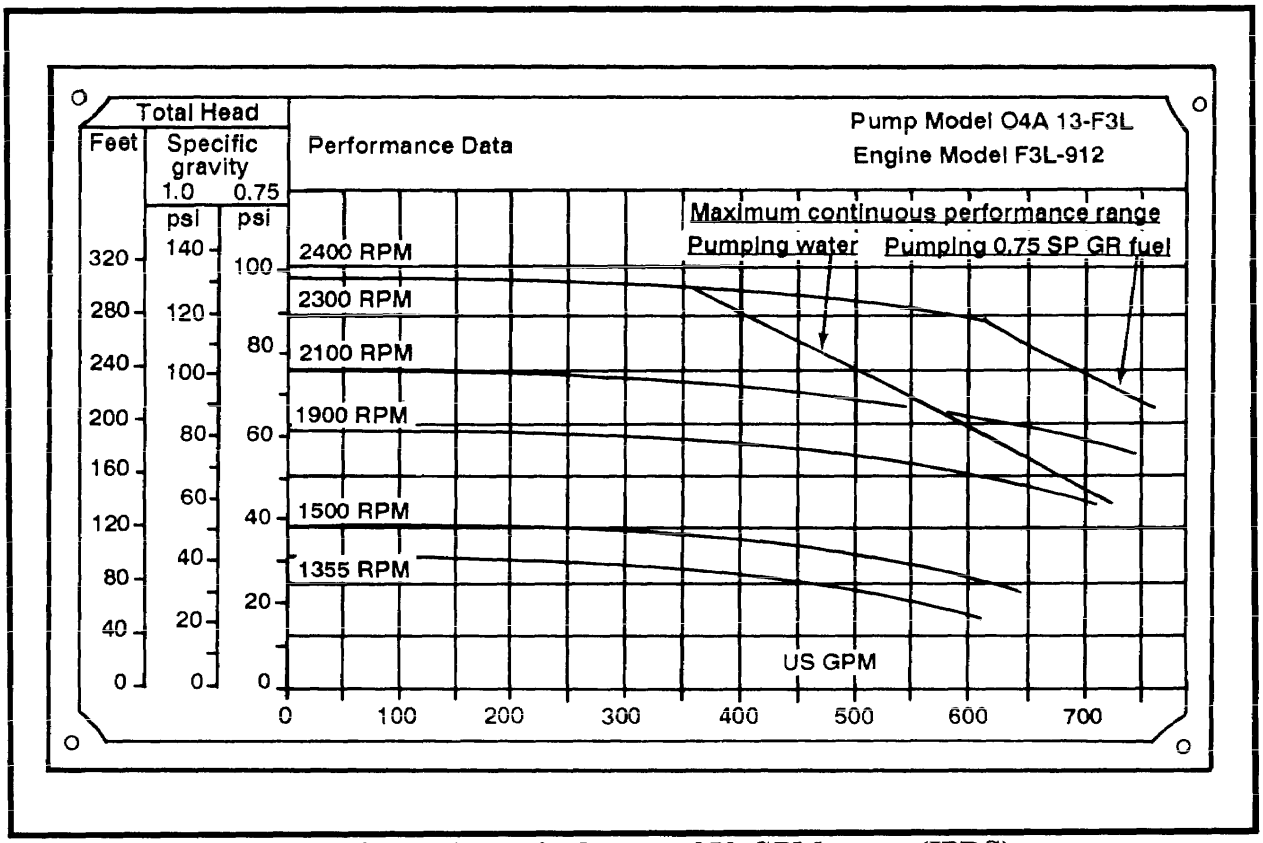


Figure C-6. 4-inch, single-stage 350-GPM pump (IPDS)

Table C-1. Friction head-loss correction factors

Temperature °F	MOGAS	JP4	CIE Diesel	JP5	DFA or VVF 800 Diesel No. 1	VVF 800 Diesel No. 2
For 12-inch Pipe						
80	1.00	1.03	1.05	1.15	1.10	1.16
60	1.00	1.05	1.09	1.19	1.13	1.23
40	1.01	1.06	1.13	1.24	1.19	1.35
20	1.01	1.09	1.16	1.32	1.26	1.54
0	1.03	1.12	1.26	1.40	1.37	(*)
-20	1.05	1.16	1.38	1.53	1.53	
For 16-inch Pipe						
80	1.00	1.04	1.07	1.17	1.11	1.18
60	1.00	1.05	1.10	1.23	1.16	1.25
40	1.01	1.07	1.13	1.27	1.20	1.39
20	1.02	1.10	1.19	1.34	1.28	1.56
0	1.04	1.13	1.27	1.42	1.39	(*)
-20	1.06	1.19	1.39	1.55	1.55	
For 20-inch Pipe						
80	0.99	1.04	1.08	1.21	1.14	1.22
60	1.00	1.07	1.12	1.27	1.19	1.32
40	1.01	1.09	1.17	1.32	1.26	1.44
20	1.03	1.12	1.26	1.42	1.35	1.71
0	1.05	1.17	1.35	1.53	1.49	(*)
-20	1.08	1.23	1.53	1.71	1.71	
For 4-inch Pipe						
80	1.00	1.04	1.07	1.18	1.11	1.18
60	1.00	1.05	1.09	1.23	1.16	1.25
40	1.01	1.08	1.14	1.27	1.20	1.40
20	1.03	1.10	1.19	1.34	1.28	1.62
0	1.04	1.14	1.27	1.45	1.39	(*)
-20	1.07	1.19	1.43	1.62	1.55	
For 6-inch Pipe						
80	1.00	1.04	1.06	1.17	1.11	1.17
60	1.00	1.05	1.09	1.21	1.15	1.25
40	1.01	1.08	1.13	1.25	1.20	1.37
20	1.03	1.10	1.19	1.32	1.28	1.57
0	1.04	1.14	1.27	1.43	1.40	(*)
-20	1.07	1.19	1.41	1.57	1.57	
For 8-inch Pipe						
80	1.00	1.03	1.06	1.17	1.10	1.17
60	1.00	1.05	1.09	1.20	1.18	1.25
40	1.01	1.07	1.13	1.25	1.19	1.37
20	1.03	1.10	1.18	1.32	1.27	1.56
0	1.04	1.13	1.26	1.42	1.39	(*)
-20	1.06	1.16	1.39	1.56	1.56	

*The pour point of VVF 800 Diesel No. 2 is 10°F.

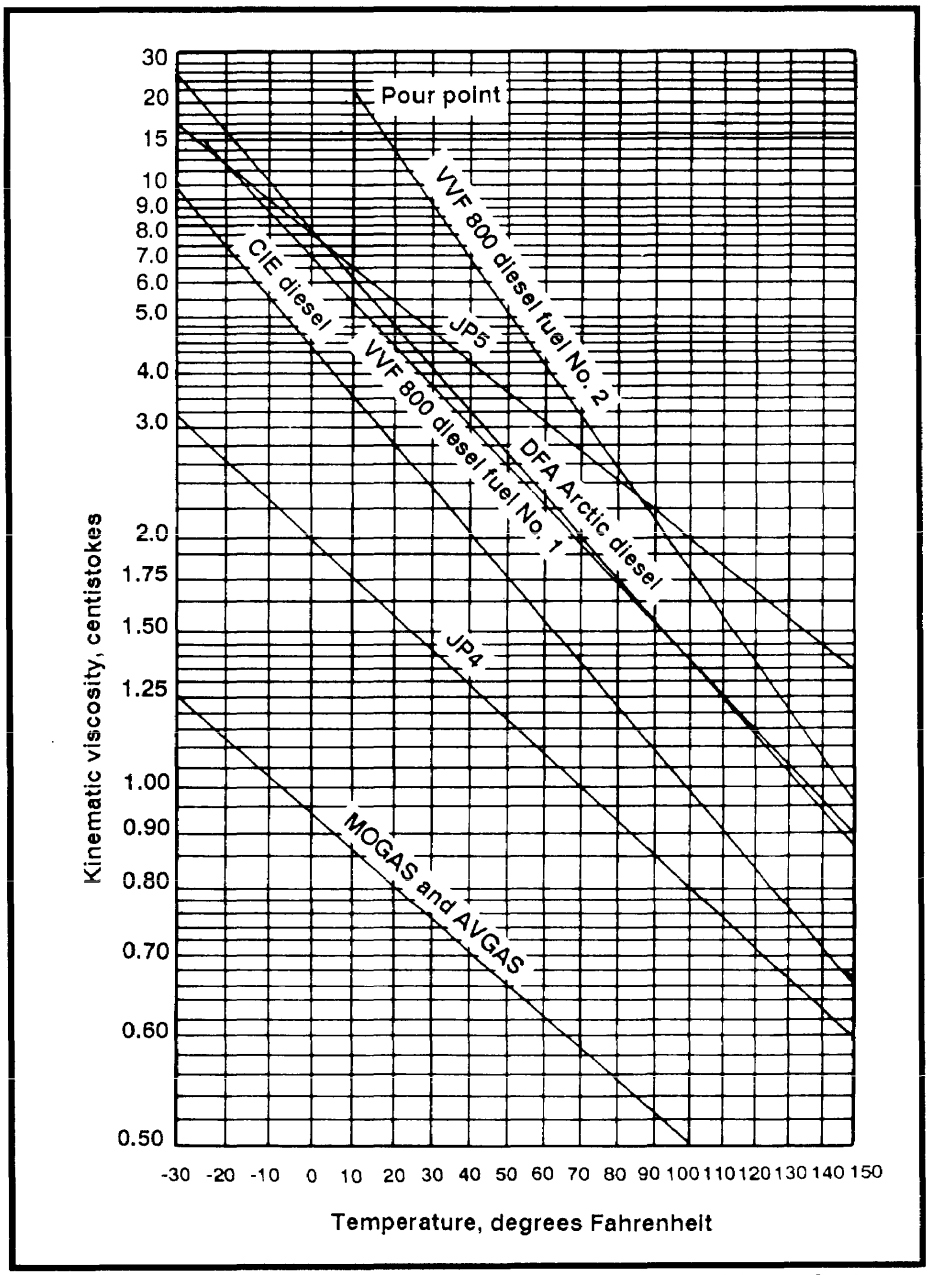


Figure C-7. Kinematic viscosities for common military fuels

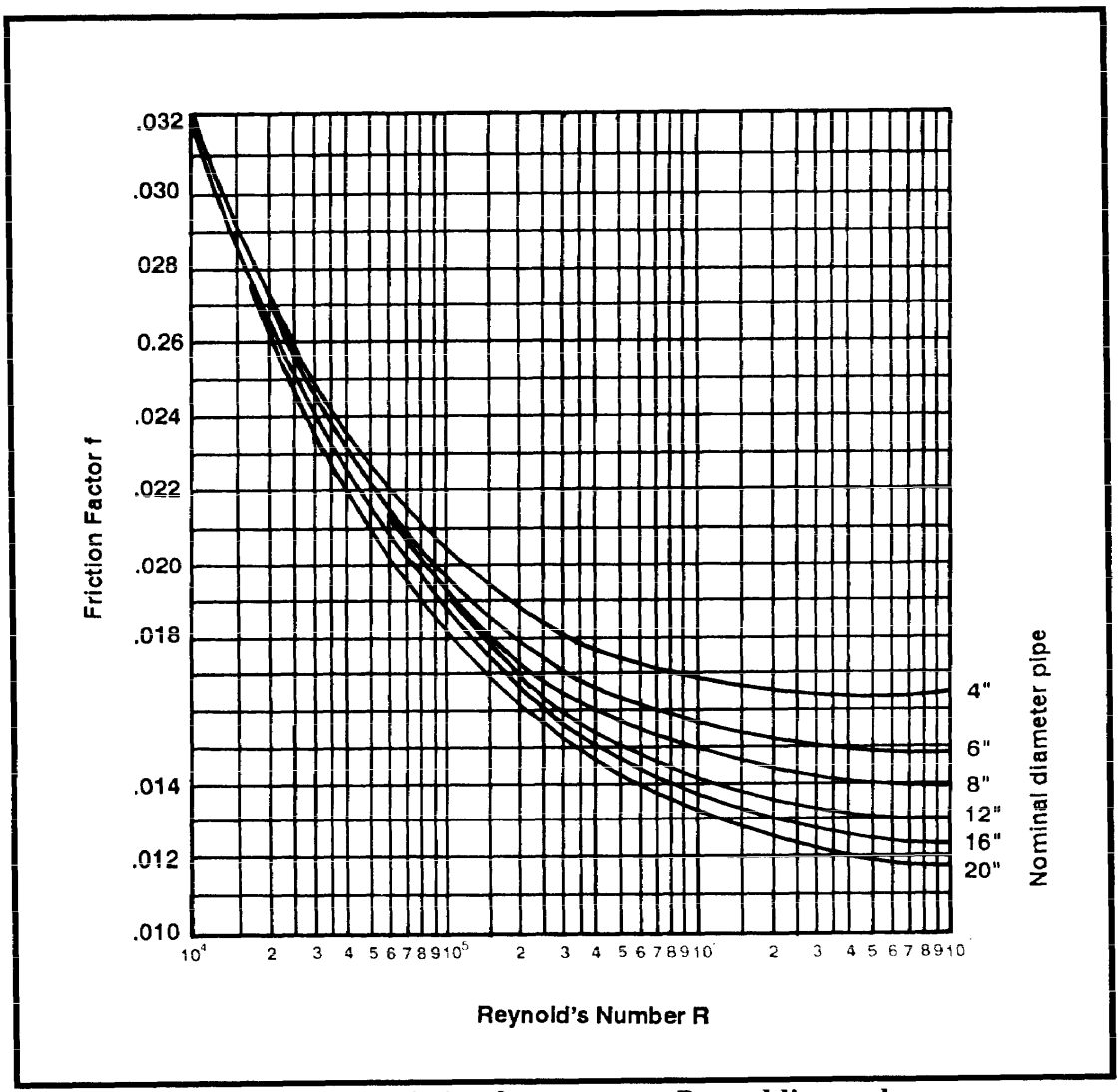


Figure C-8. Friction factor versus Reynold's number

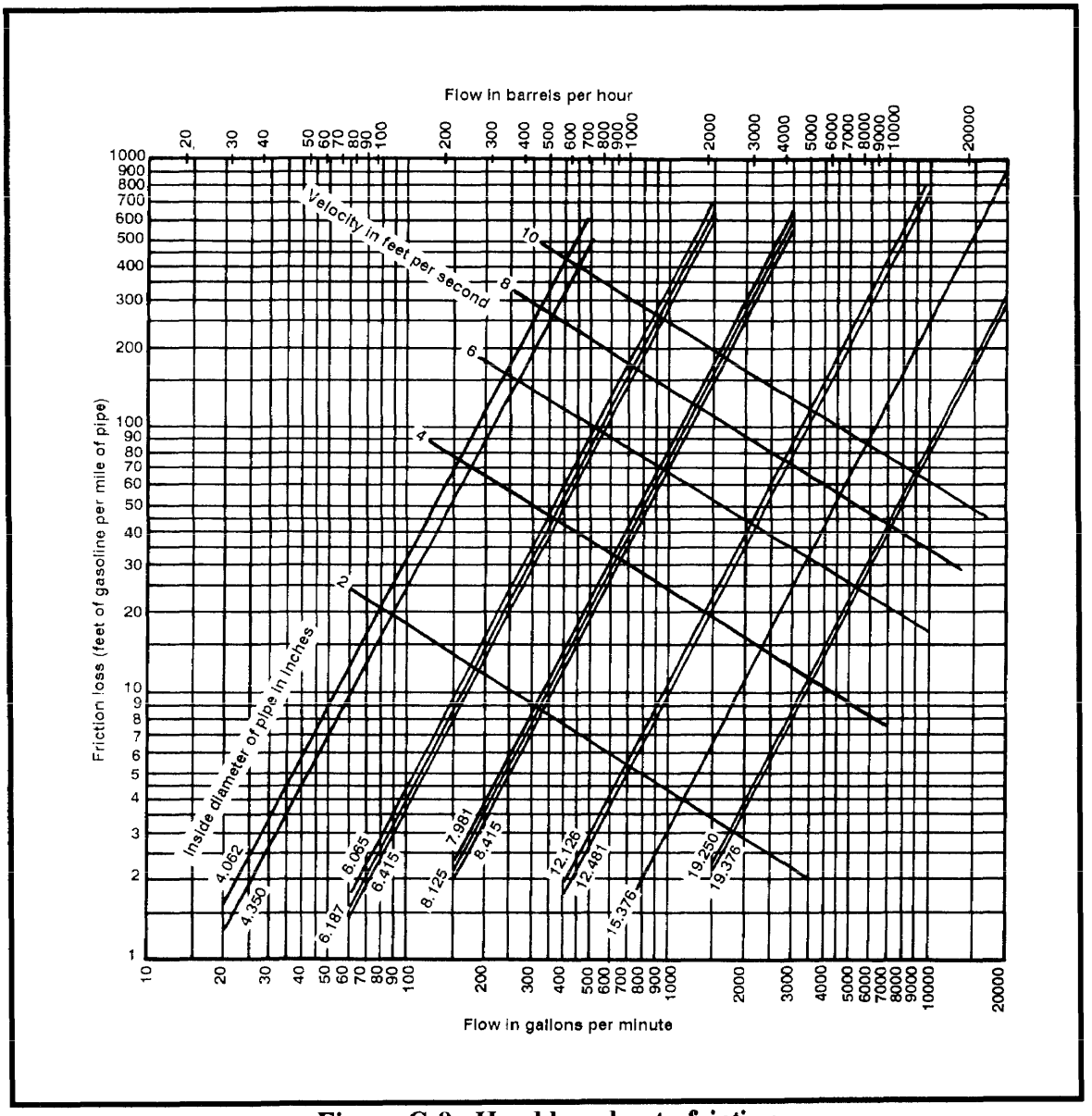


Figure C-9. Head loss due to friction

Glossary

4-inch, single-stage, 350-GPM pump *See* **350-GPM transfer pump.**

4-ton bolster trailer A dual-axle trailer, with 4 bolster attachments and an adjustable tow boom, used for transporting pipe from the construction staging areas to the construction site.

5-mile pipeline set Consists of the pipes, valves, elbows, anchors, couplings, gaskets, and other materials needed to build 5 miles of pipeline.

5-ton cargo long bed A truck that is the primary vehicle for construction of military pipelines; the truck is used to pull the 4-ton bolster trailer, transport the pipe to the construction site, and haul equipment and soldiers to and from the construction site.

6-inch, bolt-on-type, hose-to-cam-lock, male and female adapter Device that is installed on the ends of the 6-inch hose-and-reel kit.

6-inch, cam-lock, female-by-double-grooved adapter Device that is connected to the cam-lock gate valve on the discharge line leading to the 210,000-gallon, collapsible fabric tank.

6-inch, cam-lock, male-by-double-grooved adapter Device that is connected to the hose that goes to the elbow coupler on the tank inlet.

7 1/2-ton crane Used for lifting and placing scraper-receiver assembly, strainer assembly, launcher assembly, and valves along the pipeline and at pumping-station locations.

12-foot, noncollapsible, discharge, 4-inch hose Used in the contaminated-fuel module and the 50,000-gallon, TPT, optional-tank configuration.

12-foot, noncollapsible, suction, 6-inch hose Used in the tank-farm assembly and tanker-truck receipt manifold.

12-foot, suction, 4-inch hose assembly Used in the tanker-truck receipt manifold; contaminated-fuel module; and the 50,000-gallon, TPT, optional-tank configuration.

40-ton crane Used for lifting and placing mainline pumps at construction staging areas and at pumping-station locations.

50- and 500-foot, lightweight, collapsible, discharge, 6-inch hose Used in the tank-farm assembly, contaminated-fuel module, tanker-truck receipt manifold, switching manifold, and fuel-dispensing assembly.

350-GPM transfer pump An air-cooled, 3-cylinder diesel engine and a self-priming centrifugal pump mounted on a 2-wheel frame assembly; this pump is used as part of the contaminated-fuel module to load a tanker-truck with off-specification fuel for disposal or blending. *See also* **600-GPM hose-line pump; 800-GPM mainline pump; 1,250-GPM hose-line pump; centrifugal pump; flood-and-transfer pump.**

600-foot, 6-inch hose-reel assembly Consists of 600 feet of 6-inch lightweight hose packaged on reels; MAWP is 150 psi.

600-GPM hose-line pump A wheel-mounted, variable-speed, self-priming centrifugal pump with manual and automatic controls and a turbocharged, air-cooled, 6-cylinder diesel engine; this pump is a component of the tank-farm assembly. *See also* **350-GPM transfer pump; 800-GPM mainline pump; 1,250-GPM hose-line pump; centrifugal pump; flood-and-transfer pump.**

800-GPM mainline pump A skid-mounted, diesel-engine-driven, centrifugal, 3-stage, high-pressure pump with an output of 800 GPM at 1,800 feet of head; this pump is used as a booster pump on the IPDS pipeline. *See also* **350-GPM transfer pump; 600-GPM hose-line pump; 1,250-GPM hose-line pump; centrifugal pump; flood-and-transfer pump.**

1,250-GPM hose-line pump A skid-mounted, 6-cylinder, single-stage, turbocharged, diesel engine; this pump is in the IPDS and is used for flood, transfer, and general utility service. *See also* **350-GPM transfer pump; 600-GPM hose-line pump; 800-GPM mainline pump; centrifugal pump; flood-and-transfer pump.**

6,000- and 10,000-pound rough-terrain forklift Used to load and unload pipeline components at construction staging areas along the pipeline trace.

AFCS Army Facilities Components System; consists of the TMs that make up a system for rapidly determining the Class IV materials, layout, and construction effort required.

AFFF aqueous film-forming foam

AL Alabama

anchor A screw-type anchor, 1 1/2-inch square steel shaft 5 feet long with a 6-inch tapered helix welded to the bottom; the anchor is used to secure the pipeline to the ground.

anchor clamp A two-piece steel clamp used to secure the pipe to the anchor.

ANSI American National Standards Institute

API American Petroleum Institute

API gravity Scale, used by the petroleum industry, that is based on reciprocals of specific gravities and, therefore, produces whole numbers having a greater numerical spread.

AR Army regulation

Army Facilities Component System *See* **AFCS**

atmospheric pressure Comparable to static pressure in liquids because it is caused by the weight of air above the earth's surface.

ATTN attention

AVGAS aviation gasoline

AVLUB aviation lubricant

ball valve Valve used in switching manifolds to regulate the fuel flow. *See also* **check valve; gate valve; nonrising-stem valve; plug valve; pressure-control valve; pressure-reducing valve; pressure-regulating valve; rising-stem valve; thermal-relief valve.**

barrel *See* **bbl.**

base terminal *See* **pumping station 1**

batching Determining the sequence in which two or more products are to be pumped; introducing products into the pipeline in a sequence that results in the least formation of interfacial material.

bbl barrel(s); a common unit of measurement of liquids in the petroleum industry; one barrel equals 42 US gallons.

beach interface Valves and fittings needed to connect the IPDS to the OPDS.

Bernoulli equation An equation that expresses the energy relationship for a liquid flowing through a pipe between two points.

BFTA bulk-fuel tank assembly; a 210,000-gallon tank that is primarily used for initial storage at beachheads as an integral part of the TPT tank-farm complex.

blank flange A flange used to close the end of a pipe or to close a pipeline to produce a dead end; a blank flange is used to ensure that there will be no movement of product. A blind flange is not the same as a blank flange.

bolted coupling Standard, split-ring, groove-type coupling used in the steel pipeline system; this coupling provides a sufficient amount of angular deflection and slack adjustment for expansion and contraction of the line between adjacent joints.

BPH barrel(s) per hour

buffer An object (such as a hydrocarbon product) used to separate two batches in a pipeline.

bulk-fuel tank assembly *See* **BFTA**

bulk-petroleum distribution system The network that gets bulk fuel to using units; the system can consist of ocean-tanker loading and unloading facilities, storage terminals, pump stations, pipelines, hose lines, tank vehicles, and rail tank cars.

cam lock A quick-connect fitting found on valves and hoses in the TPT and low-pressure areas of pump stations.

cam-lock coupling Low-pressure, quick-disconnect coupling used on some components of the TPT and for drains in the pumping stations. *See also* **double-grooved coupling; single- grooved coupling.**

capacity Quantity of fuel pumped per unit of time, expressed in BPH or GPM. Also called **throughput.**

cathodic protection The measures taken to stop the flow of direct electrical currents from the pipeline to and through the soil in which it is buried.

cavitation Formation of a cavity or partial vacuum around a fan, propeller, or impeller that is revolving above a certain critical speed causing a loss of efficiency.

centipoise Unit of viscosity equal to 1/100 poise.

centistoke Unit of kinematic viscosity equal to 1/100 stoke.

centrifugal pump Consists of one or more impellers mounted on a rapidly rotating shaft; the liquid enters the impeller at the center (eye) and is impelled outward from the center by centrifugal force at high velocity into the volute of the pump casing. The function of the volute is to catch the impeller discharge and convert peripheral (tangential) velocity head into pressure head while conducting the liquid at a reducing rate of flow to the discharge nozzle of the pump casing. *See also* **350-GPM transfer pump; 600-GPM hose-line pump; 800-GPM mainline pump; 1,250-GPM hose-line pump; flood-and-transfer pump.**

cfm cubic foot (feet) per minute

change in length ((delta) L) Reflects change in aluminum pipe length due to thermal expansion.

check valve A one-way (nonreturn) valve whereby fluids pass in one direction only; the valve closes when the pressure causing flow stops or back pressure closes the valve. *See also* **ball valve; gate valve; nonrising-stem valve; plug valve; pressure-control valve; pressure-reducing valve; pressure-regulating valve; rising-stem valve; thermal-relief valve.**

CIMIC civil military cooperation; agreement between a host nation and the US military for the host nation to provide facilities, food, services, and labor.

civil military cooperation *See* **CIMIC**

cold bend Steel pipe-bending method; a pipe joint is pulled until stressed beyond the yield point of the material, thus causing a permanent set.

collapsible, dispensing, 1-, 1 1/2-, 2-, and 4-inch hose Used in the fuel-dispensing assembly and the 50,000-gallon, TPT, optional-tank configuration; this hose is available in various lengths.

COMMZ communications zone

contaminated-fuel module A module consisting of two 50,000-gallon, collapsible, fabric tanks used to hold fuel that is contaminated or off-specifications until it can be disposed of or blended.

contamination The addition to a petroleum product of some material not normally present. Common contaminants are water, dirt, sand, mill scale, and other petroleum products.

CONUS continental United States

coupling A clamp used to connect two pieces of pipe, hose, valves, or fittings.

critical gap-crossing set Prepackaged gap-crossing material consisting of 4-inch steel pipe, cross-braces and roller assemblies to cross a total of 250 feet of gap.

culvert pipe Standard, nestable, steel-corrugated pipe used for protecting pipelines located under roadways to minimize damage from the weight of passing vehicles.

cut-and-groove machine A portable pipe cutting-and-grooving machine used to prepare ends of IPDS pipe and piping components; this machine can cut aluminum and steel pipe to desired lengths and simultaneously cut single or double grooves.

DA Department of the Army

Darcy-Weisbach equation Used to calculate friction head loss in a pipeline.

deadweight tester Used to calibrate gauges, verify set points of spring-loaded relief valves, and provide precise pressure readings for pipelines.

Defense Fuel Supply Center *See* **DFSC.**

Defense Logistics Agency *See* **DLA.**

design fuel Fuel type for which a pipeline system is designed; military pipelines most likely will transport diesel and jet fuels and kerosene.

DFSC Defense Fuel Supply Center; procures and arranges for delivery of bulk-petroleum products to the military services; DFSC contracts with a commercial supplier in CONUS or overseas and ensures that required fuel is shipped to the theater.

differential pressure The difference between suction pressure and discharge pressure of a pump; increment of pressure added by each pump operating in series in pumping stations; pressure drop or loss between inlet and outlet of a filter, meter, or other accessory offering resistance to flow.

discharge side Downstream or outlet side of a pump having the discharge pressure of the product.

ditching Preparing the bottom for a river crossing.

DLA Defense Logistics Agency; is responsible for the integrated management of bulk petroleum; DLA works through the DFSC.

DOD Department of Defense

double-grooved coupling Low-pressure coupling used in the TPT. *See also* **cam-lock coupling; single-grooved coupling.**

downstream The direction of pipeline flow.

drum, collapsible A 500-gallon, fabric drum. (All other sizes of liquid fuel collapsible containers are considered tanks not drums.)

DS direct support

dynamic head A measure of pressure, or kinetic energy, of liquids in motion.

earthwork Tank berms, tank pads, roads, and culverts at a TPT location.

elbow An *L*-shaped pipe fitting used to form an angle between adjacent pipes; the angles are 6, 11 1/4, 22 1/2, 45, and 90 degrees for aluminum fittings and 45 and 90 degrees for steel fittings.

ENCOM engineer command; provides construction support for the petroleum facilities that are required to accomplish the theater support mission; ENCOM plans and supervises construction or renovation of ports, roads, railways, petroleum pipelines, and petroleum-storage facilities in support of the bulk-fuel distribution system; units assigned to the ENCOM are the engineer construction group, combat heavy engineer battalion, engineer pipeline construction support company, and engineer port construction company.

engineer command *See* **ENCOM**

EOL end of line

expansion device Expansion/contraction devices used to take up pipeline movement caused by thermal expansion; the two types of devices used in the IPDS are *U*-loops and *Z*-loops.

filter-separator A device used to separate solid contaminants and water from a petroleum fuel.

flood-and-transfer pump Pumps generally installed to supply the required suction pressure between tank-farm installations and mainline (trunk line) pumping stations or to feed fuel through short branch lines to dispensing installations. *See also* **350-GPM transfer pump; 600-GPM hose-line pump; 800-GPM mainline pump; 1,250-GPM hose-line pump; centrifugal pump.**

floodlight sets A 6,000-watt floodlight set consisting of a trailer-mounted, 6-kilowatt diesel generator; 30-foot expanding mast with four 1,000-watt bulbs; and two portable 12-foot masts with two 500-watt bulbs each.

flow resistance In a pipeline, fuel resists flow because of friction of the pipe walls, viscosity of the liquid, and other factors such as entrance to the pipe, sudden changes in flow direction, or resistance of valves and fittings.

FM field manual

FORSCOM United States Army Forces Command

friction loss Loss of pressure, in terms of feet of head per unit of pipe length, from internal resistance to flow in the product itself (viscosity) and from resistance offered by pipe walls, pipe fittings, and reductions in pipe diameter.

FSSP fuel-system supply points

ft foot (feet)

fuel unit Consists of three tank-farm assemblies; there are three fuel units in a TPT to allow the TPT to receive, store, and issue three types of fuel.

fuel-dispensing assembly An assembly of three 350 filter separators, valves, and hose lines used to dispense fuel from a TPT fuel-storage unit to bulk-petroleum transport.

fuel-sampling assembly A pipe section with grooved ends that consists of a 1/2-inch ball valve, 1/2-inch needle valve, goose-neck spigot, and a catch basin; this assembly is located in each TPT, upstream from the switching manifold and, where required, along the pipeline to allow periodic sampling for determining batch separation and quality control.

GAA general agency agreement

gate valve Valve with a gate that is opened or closed to control fuel flow; the locations for a gate valve are at one-mile intervals, at the bottom of hills (low points), and before and after critical gap crossings; this valve is used to stop flow at the tank or in the pipeline. A gate valve is either a rising-stem or nonrising-stem type. *See also* **ball valve; check valve; nonrising-stem valve; plug valve; pressure-control valve; pressure-reducing valve; pressure-regulating valve; rising-stem valve; thermal-relief valve.**

general mechanic's automotive set Contains an ordnance item of issue and is used mainly for minor maintenance or replacement of external accessories of pumping unit engines.

go-devil *See* **scraper.**

GPM gallons per minute

GR gross requirement

GS general support

head capacity (normal) The total head against which it will pump at the most efficient operating point. **(emergency)** The total head against which it will pump to provide maximum pipeline capacity.

head terminals May be located in the main supply areas of an independent corps.

HEMTT heavy expanded mobility tactical truck

hose-line assembly A petroleum hose-line system composed of hoses, valves, and fittings that can be readily installed to connect the major components within a TPT; there are three hose-line assemblies per TPT.

hose-reel assembly A component of the transfer hose-line assembly; the system consists of a frame, two reels, a hydraulic cylinder, a hydraulic motor, two brake systems, two 600-foot base sections, and a power pack. Hoses must be cut to desired lengths and fittings bolted on before use.

HQ headquarters

hydraulic drive head This head is used to auger anchors into the ground; it may be mounted on the bucket arm of the JD410 backhoe or the SEE.

hydraulic gradient triangle A right triangle that is constructed on the same scale as the profile; the altitude (vertical distance) represents the available feet of head pressure at the discharge of the pumping station, the base (horizontal distance) represents the distance that the fluid can be moved on level terrain, and the hypotenuse is the hydraulic gradient.

hydrometer A graduated instrument used to determine the specific gravity of liquids; it is usually made of hallow glass and weighted at one end so it will float upright. A liquid's density will determine the depth to which an instrument will sink in that liquid: the lighter the liquid, the lower the instrument sinks. Some hydrometers are marked so that the percentage of each constituent of the product in them can be read. Hydrometers used to measure petroleum are usually marked with degrees API.

hydrostatic pressure Pressure due only to the weight of the liquid itself; hydrostatic pressure goes from zero at the top of a column of liquid to a maximum at the bottom of the column.

ID inside diameter

impeller A device that impels or pushes forward, such as the rotor of a centrifugal pump or air compressor.

in inch(es)

Inland Petroleum Distribution System *See* **IPDS**

interface A mixture, or commingling, between adjacent products in a multiproduct pipeline; interfacial mixture.

intermediate terminals Serve as reserve-storage installations and as dispensing installations.

IPDS Inland Petroleum Distribution System; a rapidly deployed petroleum system consisting of aluminum pipe, pumping stations, and TPTs for use in contingency operations; an IPDS is composed of modules to provide required configurations for preplanned or emergency deployment.

ISO International Standards Organization

jackrabbit start Incorrectly starting a vehicle, causing the load to slide off the rear of the vehicle.

joint petroleum office *See* **JPO**

JP jet petroleum

JPO Joint Petroleum Office; established by the Joint Chiefs of Staff to provide staff management of petroleum at the theater level on the staff of the unified commander; the JPO submits monthly petroleum requirements of all the military services in the theater to the DFSC.

launcher assembly A skid-mounted assembly located at the discharge side of each pumping station used to launch a pipeline scraper from one pumping station to the next.

lizard *See* **traveling shield**

lb pound(s)

LOG logistics

mainline pump-station set Consists of the pumps, valves, valve launchers, receivers, strainers, light sets, and pump shelters needed to construct a standard, mainline pumping station.

MAWP maximum allowable working pressure. *See also* **working pressure.**

meter strainer A skid-mounted device that measures the quantity and flow rate of fuel moving into and out of the TPT; the strainer protects the meter.

METT-T mission, enemy, terrain, troops, and time available

MIL-STD military-standard

modular design A simplified graphical method of locating pumping stations (except station 1) and pressure-reducing stations.

MO Missouri

MOGAS motor gasoline

MSC military sealift command

MSR main supply route

MTOE modification table of organization and equipment

NATO North Atlantic Treaty Organization

NCOIC noncommissioned officer in charge

No. number

nonrising-stem valve The lower end of the stemon this valve is threaded, and it screws into the disk; the disk moves up or down while a thrust collar keeps the stem in place. *See also* **ball valve; check valve; gate valve; plug valve; pressure-control valve; pressure-reducing valve; pressure-regulating valve; pressure-relief valve; rising-stem valve; thermal-relief valve.**

OD outside diameter

Offshore Petroleum Discharge System *See* **OPDS**

OIC officer in charge

OPLAN operations plan

OPDS Offshore Petroleum Distribution System; a Navy system that uses a ship, which is anchored up to 4 miles offshore, and underwater hose lines to off-load commercial tankers and deliver fuel to the high-water mark in an undeveloped theater.

overcoupling clamp A clamp in two halves used to enclose a leading coupling.

P/L petroleum/lubricant

petroleum terminal Made up of a single tank farm or a complex of dispersed tank farms with varying capacities.

packed line A petroleum pipeline or hose line filled with product under pressure.

pig *See* **scraper.**

pig walkers crew members.

pipe-fitter's general tool kit Contains a variety of hand tools needed for all types of pipe fitting to work on 1/8- to 2-inch pipe.

pipe-fitter's supplemental tool kit Contains a minimum of hand tools required for cutting, threading, and fitting the 2 1/2- to 4-inch pipe; supplements the pipe-fitter's general tool kit.

pipe fittings Standard, groove-type fittings that include elbows, *Ts*, reducers, blank ends, and adapters.

pipeline-construction, grooved-coupling, steel-tubing set Contains the tools and equipment needed to construct and maintain steel-coupled-type pipelines and pumping-station manifolds.

pipeline strainer assembly Consists of skid-mounted dual strainers and associated valves and piping; assembly is supplied with the IPDS for installation in the pipeline pumping stations upstream of the pumps.

pipeline suspension-bridge set Consists of towers, guy wires, deadman anchors, cables, suspenders, and other materials needed to construct a bridge; assemblies are available in 100-, 200-, and 400-foot kits.

pipeline valves These valves cut off, control, and direct the fuel flow in a pipeline.

pipeline vent assembly A 1-foot-long section of steel pipe with a 3/4-inch weldolet coupling and a 3/4-inch ball valve, fittings, and nipple; vent assemblies are installed at high points to vent air from the pipeline.

pipe saw A reciprocating-type saw powered by an air motor that can cut steel, cast iron, and stainless or alloy steep pipe; this saw has an 8-inch capacity for hazardous locations.

pit-leak clamp Used to stop a small hole caused by corrosion or other damage. *See also* **repair clamp; split-leak clamp.**

plot plan A dimensional layout of major equipment involved in a system.

plug valve Valve that has a revolving plug with an opening so that fuel flows when the opening is aligned with the pipe; used in a tank-farm manifold and on launchers and receivers where quick and positive closing of the valves is essential. *See also* **ball valve; check valve; gate valve; nonrising-stem valve; pressure-control valve; pressure-reducing valve; pressure-regulating valve; rising-stem valve; thermal-relief valve.**

POL petroleum, oils, and lubricants

pressure-control valve (5 psi) A 1 1/2-inch pressure-control valve used in the fuel-dispensing assembly when filling nonvented, 500-gallon, collapsible drums; limits the flow pressure to 5 psi. **(30 psi)** A skid-mounted, 6-inch back-pressure relief/regulator valve installed in the recirculating hose line from the fuel-dispensing assembly to tankage to maintain dispensing pressure of 30 psi. *See also* **ball valve; check valve; gate valve; nonrising-stem valve; plug valve; pressure-reducing valve; pressure-regulating valve; pressure-relief valve; rising-stem valve; thermal-relief valve.**

pressure-regulating valve A steel, skid-mounted, dual-control, 4-inch valve used to regulate pressure of fuel entering a TPT and to maintain an upstream pressure above a set point (50 psi) and a downstream pressure below a set point (125 psi). *See also* **ball valve; check valve; gate valve; nonrising-stem valve; plug valve; pressure-control valve; pressure-reducing valve; rising-stem valve; thermal-relief valve.**

product control Those actions necessary to control and safeguard products in TPT storage or flowing through the pipeline; product control includes pumping orders, flow schedules, supply control and accounting, quality surveillance, and monitoring the integration of the system.

psi pound(s) per square inch

psig pound(s) per square inch gauge

pumping station An area that has two 800-GPM mainline pumps; a launcher, receiver, and strainer assembly; and associated pipe, valves, and fittings that are used to boost the pressure of fluid flowing through the pipeline.

pumping station 1 The station that receives fuel from a petroleum-terminal tank farm or host-nation supply. Also called **base terminal.**

pup joint A 9 1/2-foot-long pipe section with a constant wall thickness of 0.4 inch; this joint is used to make short pieces of pipe or nipples, which can be cut and regrooved, that are used to close gaps less than 19 feet.

quality surveillance Measures taken to ensure that petroleum products, which the government has accepted as being of the required quality, are still of the required quality when delivered to the user; quality surveillance includes watching over and caring for products during all storage and handling operations, adhering to handling methods and procedures designed to protect quality, and examining and testing products in storage and on change of custody.

receiver assembly A skid-mounted assembly located on the incoming side of each pumping station and at end-of-line used to receive a pipeline scraper launched from the preceding pumping station.

reducer A coupling that has one end larger than the other; a reducer is used to connect pipes or pipes and other fittings of different diameters.

repair clamp A clamp supplied in one of three types for the temporary repair of leaking pipes or couplings. *See also* **pit-leak clamp; split-leak clamp.**

reverse polarity Positive electrode and negative work; recommended use in welding when using shielded arc electrodes.

Reynold's number An equation used to determine the friction factor required in the Darcy-Weisbach equation.

rising-stem valve A type of gate valve in which the valve stem and disk rise together when the valve is opened. *See also* **ball valve; check valve; gate valve; nonrising-stem valve; plug valve; pressure-control valve; pressure-reducing valve; pressure-regulating valve; thermal-relief valve.**

RPM revolutions per minute

S&I standardization & interoperability

S&P stake and platform

S3 Operations and Training Officer (US Army) (S3)

SALMS Single-Anchor Leg-Mooring System

SB supply bulletin

scraper A device propelled by the moving stream in a pipeline used to scrape out or dislodge wax, corrosion, sediment, air, or other deposits that tend to increase friction loss, reduce throughput, or lead to contamination of product; scrapers are dispatched from a launcher and received in a receiver. The outgoing barrel is on the discharge side of a pumping station; the incoming barrel is on the suction side. Also called **pig; go-devil.**

sec second(s)

sediment Foreign matter other than water that settles to the bottom of a container.

SEE small emplacement excavator; used to install pipeline anchors, dig and back fill culverts, and load and unload gate and check valves.

settling time The elapsed time that a product remains undisturbed or unagitated between receipt of product into and discharge from storage.

SG specific gravity; physical property of liquids; SG is the ratio of the weight of a volume of liquid to the weight of an equal volume of water.

single-grooved coupling High-pressure coupling used in the IPDS pipeline and pumping stations; an IPDS single-groove coupling gasket is not interchangeable with double-grooved or victaulic single-grooved gasket. *See also* **cam-lock coupling; double-grooved coupling.**

slack line A pipeline that has been shut down without pressure; static pressure is caused by differences in elevation along the profile.

small emplacement excavator *See* **SEE**

specific gravity *See* **SG**

split-leak clamp Consists of stirrups, a saddle, and a gasket to be fitted around the pipe at a fault. *See also* **pit-leak clamp; repair clamp.**

STANAG standardization agreement

standby A term for equipment used only in emergencies or, in the case of pumping units in a pumping station, on a rotational basis for uniformity of wear and for maintenance purposes.

static head Hydrostatic pressure produced with a column of liquid at rest.

station on a downgrade A downstream pumping station that is at a lower elevation than the preceding station.

station on an upgrade A downstream pumping station that is at a higher elevation that the preceding station.

std standard

strainer assembly Skid-mounted assembly on the suction side of pumping stations used to filter particles out of the product being pumped, thus protecting the pumps; an assembly has two strainers so one can be bypassed and cleaned without interrupting the flow.

stringing Off-loading and placing pipe sections along the pipeline route end to end.

suction pressure Pressure on the inlet or suction side of the pump.

supplemental pipeline pumping-station set Contains all the tools required for operator maintenance and repair of the standard pumping units and the 4-, 6-, and 8-inch pumping-station manifolds; supplements the general mechanic's tool set.

suspension bridge Precut and prepackaged bridges available in 100-, 200-, and 400-foot sizes; the bridges are part of IPDS material for laying pipeline across streams and ravines.

switching manifold The nerve center of a TPT that allows fuel to be received from the pipeline or tanker-truck receipt manifold and moved into any of fuel units or between fuel units back into the pipeline.

tactical petroleum terminal *See* **TPT.**

TAMMC Theater Army Material Management Center; is the theater petroleum item manager for bulk-petroleum products; TAMMC records consumption data, coordinates with the petroleum group to program future requirements, and submits petroleum requirements for the theater to the JPO.

tank A 210,000-gallon, collapsible, fabric tank, in the IPDS, for storage of petroleum products; there are two tanks per tank-farm assembly, with three tank-farm assemblies per fuel unit and three fuel units per TPT.

tank-farm assembly The basic storage unit in a TPT consisting of two 210,000- gallon, collapsible, fabric tanks; one 600-GPM hose-line pump; and associated hose, valves, and fittings. Three tank-farm assemblies make one fuel unit.

tanker-truck receipt manifold The hoses, valves, and fittings necessary to give a TPT the capability of receiving products from tanker trucks; there are three manifolds per TPT, one for each fuel unit.

tapping machine A lightweight drilling machine with an adjustable, automatic feed rate used to tap into a pressurized pipeline to drain for pipe or coupling replacement.

temperature A physical property of liquids that affects viscosity, density, specific gravity, and other physical properties; all measurements are corrected to 60°F.

terminal A bulk facility for receipt, storage, transportation, and issue of petroleum products; the facility may be a base terminal for receipt and shipment of product by tanker, a pipe-head terminal (head terminal) at the downstream end of the pipeline, or an intermediate terminal on the pipeline. The terminal consists of a tank farm or tank-farm complex, tank-farm manifold, and central pumping-station area.

theater army Provides broad planning guidance for Army petroleum support, supervises current operations, and conducts long-range planning.

Theater Army Material Management Center *See* **TAMMC**

thermal-relief valve An automatic valve used to release pressure above a given setting; valves are set 10 percent above the maximum pipeline pressure. *See also* **ball valve; check valve; gate valve; nonrising-stem valve; plug valve; pressure-control valve; pressure-reducing valve; pressure-regulating valve; rising-stem valve.**

throughput *See* **capacity**

tie-ins Welding unconnected sections together.

TM technical manual

TO theater of operations

TOE table(s) of organization and equipment

TPT tactical petroleum terminal; a fuel-handling system designed to receive, store, and issue bulk-petroleum fuels, specifically diesel and jet fuels, from the pipeline or tanker trucks to bulk-petroleum vehicles or 500-gallon collapsible drums; a TPT consists of nine tank-farm assemblies (two 210,000-gallon tanks each) in three fuel units, allowing storage of three separate products.

TPT set Eighteen 210,000-gallon fabric tanks and the necessary assemblies to receive and issue fuel at the retail level.

TRADOC United States Army Training and Doctrine Command

traveling shield Device that is pulled ahead of the backfilling machine to absorb the impact of the earth being placed in the trench over the pipe. Also called **lizard.**

twin agent unit A trailer-mounted fire extinguisher using dry chemical and AFFF to suppress petroleum fires in a TPT.

***U*-loops** *See* **expansion devices.**

upstream Opposite to the direction of pipeline flow, which is downstream.

US United States (of America)

USAEDH United States Army Engineer Division, Huntsville

valve A device used to control flow of fluids and regulate the flow of gases, liquids, or loose materials through structures, such as piping or hose lines, by opening and closing or by obstructing ports or passageways.

vapor pressure A function of the temperature and pressure of the system.

viscosity Physical property of liquids; viscosity is a measure of the flow of a liquid; it is the internal force (resistance) or opposition to flow.

w/ with

weight density Physical property of liquids; density is a measure of the concentration of matter; weight is a measure of the force of gravity; weight density is the weight per unit of volume.

welded pipeline construction set (4-, 6-, and 8-inch size) Contains the special size equipment in the correct quantities required for handling the three pipe sizes, stringing pipe sections, and laying and welding the pipeline. **(12-inch size)** Contains the special size equipment in correct quantities needed for handling, stringing, laying, aligning, and beveling 12-inch pipe.

welder's supplemental pipeline construction set Contains the tools and equipment required for welded pipeline construction that are not in the oxyacetylene torch outfit, cutting-and-welding equipment set.

working pressure The maximum allowable pressure at which a system or piece of equipment is designed to operate safely; the IPDS pipeline and pumping stations have a MAWP of 740 psi; the TPT has a MAWP of 150 psi.

wrinkle bend Pipe-bending method; an accurately controlled bend can be made using an acetylene torch to heat the pipe (not tubing) to produce an area of relative weakness that will produce an outwardly projecting wrinkle in the bent portion of the pipe.

***Z*-loops** *See* **expansion devices**

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